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Japan Report

SCIENCE AND TECHNOLOGY

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JAPAN REPORT

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SCIENCE AND TECHNOLOGY

CONTENTS

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NEW MATERIALS

NEW MATERIALS ROLE AS LEADING TECHNOLOGY EXAMINED

History, Potential Viewed

Tokyo PUROMETEUSU in Japanese Sep-Oct 85 pp 12-14

[Article by Shinroku Saito, president, Nagaoka Institute of Technology]

[Excerpts] It is evident that new materials have played a leading role at the start of each phase of the history of technology. The author will not repeat here the well-known categorization of history into the stone, bronze, and iron ages. However, the industrial revolution, the dawn of modern technology, was based on quantity production of iron by invention of the coke oven. A revolutionary change occurred in man's mind at this juncture concerning the use of iron and, more generally, metallic materials. Man conceived the idea of using these materials for heat resistant purposes. Previously, the materials had been used only at normal temperatures in, for example, weapons, armor, kitchen utensils, and components of buildings. Men today need not feel either resistance against or curiosity for the use of metals at high temperatures. The invention of steam engines by Watt opened the way toward the use of materials at high temperatures and developments led to using first, simple iron, and then alloys. The effects of carbon on the properties of steel had been studied and ready for application by the eve of the industrial revolution. This suggests that a revolution in the minds of people had been quietly in progress before the actual industrial revolution took place. The discovery of superplasticity in carbon contents close to that of cast iron, incidentally, is a recent topic of conversation.

In terms of history, 200 years after the emergence of these new requirements for metal properties, ceramics was unexpectedly spotlighted as a high-strength material with great resistance to high temperatures. Ceramics had, until then, been a representative of fragile products. Just as research on the iron carbon system had been the precursor of the development of ferroalloys, the forerunner for the creation of the concept of high-strength ceramics was a ceramic for use in cutting tools involving largely alumina and invented in the Soviet Union toward the end of World War II. This materialized with the evolution of a ceramic which is competitive with super-rigid alloys and, since ceramics inherently have high resistance to heat, high hopes have been pinned, of necessity, on the development of high-strength ceramics in the high temperature area.

In the United States researchers during the same period worked on cermet, a modification of the alumina tools of the Soviet Union. The alumina metal system and titanium carbide metal system, however, failed to exhibit the expected performance, rendering attempts to obtain a high-temperature material for use in gas turbines unsuccessful. Professor Jack of New Castle University, in turn, did research on Sialon, a material of the silicon nitride alumina series, during the 1960's and 1970's, which was a breakthrough in research on ceramics as a high-strength material of great heat resistance. This put research on the right track, as can be seen today.

The revolutionary concept demonstrated by Sialon has given a new impact to development of the new area of nonoxide ceramics derived from research on various nitrides, carbides, and borides. After many trials and errors, the cermet series referred to above has been put on the market as an excellent cutting tool. It is a composite material of oxide carbide involving alumina, titanium, and carbide, but lacking the metal of the original composition and, hence, is an unexpected outcome.

These developments have gathered momentum since the United States adopted, as development targets, silicon nitride, silicon carbide, and zirconia, which are to be used as materials for high-performance gas turbines in tanks. The AGT (advanced gas turbine project) was started with the participation of West Germany, from NATO. The narrow cabin of the tank benefits from cutbacks, in large measure, in cooling equipment by virtue of the heat resistance of these. ceramics. The probability of the tank getting hit by enemy fire also goes down. This project has been the focus of attention of such European car manufacturers as Benz, Renault, and Volvo. The U.S. forces of GM and Ford and Japanese carmakers are also embarking on research and development. Japanese forces, lacking military objectives, are largely grappling with reciprocal movement engines such as diesel and gasoline. However, components having prospects of materialization in the near future include heat-insulating manifolds, auxiliary combustion chambers, and turbochargers. As for fuels, however, wider consideration is needed for hydrogen and methanol.

The change in concepts for metals and ceramics and related technologies have served each other as "seeds" and "needs," as seen above. This kind of developmental relationship is also notable in a series of functional materials, for example, semiconductors, magnetic materials, high dielectrics, and optoelectronic materials. In earlier history of these materials, one can see a compass vehicle from early China and magnetic needles from the great navigation era of Columbus, each displaying ingenious functions. In terms of the history of technology, the emergence of iron as an electromagnetic material marked the so-called second phase of the industrial revolution, wherein the machine industry underwent a revolutionary change with motors and transformers spotlighted as products based on materials. It was not until the end of World War II, however, that full-fledged research on the related functions was begun.

Research on oxide magnetic materials was proudly begun by Japan before World War II, but the material then found application only as a compound in Yagi antennas toward the end of the war. The first magnetic tape that showed up in Japan was a paper tape trial manufactured by Professor Hoshino of Tokyo

Industrial University. It is indeed true that magnetic tapes of today which are capable of clear recording and playing back, and have diodes and transistors which had been invented in sequence, constitute the major incentive for the development of today's functional devices. However, one should not overlook the existence of this pioneering work of Professor Hoshino in a nation that has always been subjected to criticism for lack of creativity. This is a serious question which is associated, in large measure, with the future prospects of Japan.

In the recent trend of functional materials, polymers and biological materials are entering into a phase of major changes. Polymer materials, in terms of the history of civilization, are deeply associated with the life of man, i.e., clothing, food, and housing. The existence of polymer materials began to be discussed, however, only from around 1920. Staudinger may be cited as a representative character of the time. Thereafter, in a relatively short period, synthesis of polymer materials ranging from polyethylene to nylon was accomplished. One is reminded of the manufacture of ebonite, made by admixing sulfur to rubber, even before the concept of polymers was created. It was only after World War II that polymers were introduced to Japan as a new material. This caused people in the fiber and textile industries in Japan to frequent the Monte Catini Corp. of Italy (presently the Monte Edison Corp.) to acquire polypropylene technology. Though the material has poor affinity for dyes and was a failure as a fiber, it still is a major polymer product. Polymer material then ceased to be merely a raw material for garments and became a construction material. It further found uses in permeation and separation membranes and, finally, by coupling with biotechnological materials, was used in a membrane for immobilizing enzymes, thereby creating a new industry. The mosaic type of polymer membrane, where the surface has areas of both positive and negative potential, may be reckoned among the recent achievements of Japan. It is also notable, at this juncture, that new materials different from conventional functional materials are being brought out in succession in this sector. Examples include a charge transfer complex, such as TIF and TCNQ, electroconductive polyacethylene, the highly dielectric PVdF and the pigment melanin. Also in the limelight are, as an IC element, chemical hole-burning materials (CHB) with a capacity for multiple memory, polymer hydrogels of high expansion, star-bursting polymers, and LB films. Biological polymers, meanwhile, form the core of the so-called biotechnology materials and include such novel applications as biochips and biomotors. Elucidation of the mechanism of the transmission of information in a live body must provide a clue to the creation of a new information culture.

No scientific achievement in the modern era has had a greater impact than the finding that biological polymers are made up of no more than 20 amino acids, and DNA of four salts such as A (arginine), G (guanine), C (cytosine), and T (thionine). This finding provided an opportunity for biology, agriculture, forestry, fishery, medicine, and physiology to be discussed in a common language for the first time, which reminds one of the expected role of Esperanto. Subsequent achievements are dazzling indeed. Meanwhile, the question of how the property of raw materials manifests itself has long been discussed. Quality control, QC, though used in the sense of controlling product quality, provides neither the basic concept for the manifestation of material

characteristics nor the technology. From the standpoint of characterization, the specific properties of a raw material are unequivocally determined in accordance with its composition of elements, atoms, molecules, crystalline arrangement, internal stresses, defects, impurities, shape, and surface structure, among other things. Specific properties and structure of biological polymers definitely lend support to this.

Attempts have been made to find a common language also for all metals, ceramics, and general polymers. The problem, however, has yet to be solved. Since the assessment of raw material and estimation of its lifespan would be much clearer and more definite if such a background system were established, the question is a major future problem.

Raw Materials S&T Prospects

Tokyo PUROMETEUSU in Japanese Sep-Oct 85 pp 15-20

[Article by the Office for the Enhancement of the Development of Raw Materials, General Research Division, Research Coordination Bureau, Science and Technology Agency]

[Text] Significance of Enhancement of S&T for Raw Materials

New raw materials have had enormous effects on the economy of the community to date. The emergence of new materials has permitted exploration of new technologies, produced qualitative changes in related technologies, and had a major impact on society as well as on industry. Much of the revolutionary research and development on unexplored pioneer fields, has sought new expansion in raw materials, particularly in recent years. This has been true in the sectors of high technology such as information, electronics, and of biotechnology. S&T of raw materials is, indeed, of growing importance in order to push toward creative R&D and to promote the prosperity of Japan in S&T. Increasing importance is being attached to the development of raw materials also in large-scale projects which are being pushed presently by the government and which concern ultrahigh-speed computers, nuclear fusion, and space and ocean developments, among other things. Raw materials adapted to each of these projects is being pursued.

Under the circumstances, creation of new raw materials has grown to be a matter of extreme national importance. The government is pushing forward a variety of policies with the Science and Technology Agency (STA), the Ministry of International Trade and Industry (MITI), and the Ministry of Education (MOE) taking the lead. The Council of Science and Technology, in turn, stressed also the importance of the enhancement of S&T for raw materials in its reports submitted to date to STA. In an article titled "On the Basic Policy of Science and Technology From a Long-Term Viewpoint" included in its sixth report in May 1977, the council noted the S&T of raw materials as leading and basic for a new technology revolution and to play the part of guiding the development of many other areas of S&T. Furthermore, in "On the Basic Policy for the Enhancement of Science and Technology From a Long-Term Viewpoint Adapted to a Changed Situation," its 11th report, submitted to STA in November 1984, it rated this S&T

as necessary to activate the economy, and as basic to the prospects of new developments.

STA, on the basis of these reports, has had the Council of Aeronautics, Electronics, Etc. study measures for tackling related major technological problems. In August 1980, the council made a fifth report called "On the Enhancement of Comprehensive Research and Development for Science and Technology in Hazardous Environments and of Important Raw Materials" and indicated guidelines for general R&D on S&T in hazardous environments such as superhigh pressure, ultralow temperatures, superhigh temperatures, and on related raw materials.

Recently, against the background of increased data for raw materials and developed technologies for information processing, a trend has emerged for creating new raw materials more efficiently than with conventional methods based on trial and error. The Council of Aeronautics, Electronics, Etc., submitted its seventh report, "On the Enhancement of Comprehensive Research and Development in the Creation of New Raw Materials of the Theory for Raw Material Designing," and devised comprehensive policies for enhancing new raw materials based on raw material designing. In connection with R&D of future new raw materials, increased importance, in turn, is attached to related basic technologies such as those of measurements and beams. Investigations, therefore, are underway by the same council "on the major problems involved in, and policies for the enhancement of, the sophistication of measurement and control technologies related to R&D of new raw materials."

Present State of R&D of Raw Materials

A variety of R&D areas is being pushed ahead on the S&T of raw materials by each of the government ministries and agencies against a background of diverse and widespread needs. Private concerns, the mainstay of technological revolution, are in turn also charging ahead with R&D of new raw materials, creating a new raw materials boom.

The author's agency implements coordination of the estimates, made by other ministries and agencies, on the budgets for S&T of raw materials while at the same time pushing ahead, in a comprehensive manner, R&D of S&T by making the best of funds for enhancing and coordinating of S&T. The agency also has its National Research Institute for Metals and National Institute for Research in Inorganic Materials, among other things, which are pushing forward basic and leading R&D, just as it makes the best of the system of the exploratory research for advanced technologies for the same purpose. In support of related research, meanwhile, the Japan Information Center on Science and Technology (JICST) has been collecting, maintaining, and providing to the public information on raw materials.

The fund for the Enhancement and Coordination of Science and Technology, set up in FY 1981, as at this juncture had S&T of raw material included as a major item since FY 1982. Since FY 1985, research has moved forward on eight subjects. These include "research on basic technologies for creation of new raw materials by means of hybridized structure design technology," in which national experiment and research organs, universities, and private concerns have taken part.

FY 1985 has seen, in particular, "Research on Technologies for Practicing, Measuring, and Utilizing Superhigh Temperatures," a new research item, with a view to bringing out new raw materials by means of superhigh temperatures of 4,000°-10,000°C. Research based on this fund has been achieving impressive results to date. For example, development of a superhigh-pressure generator of the highest level in the world was attained (100,000 atms, 1,000 cm^3). The National Research Institute for Metals has been pushing forward wide ranging research on metallic raw materials in general since the institute was set up in 1956. The institute has, since FY 1985, embarked on research associated with the development of lightweight raw material with good heat resistance composed of an intermetallic compound. The institute reinforced its basic research section for R&D of new raw materials by setting up three new sections--for raw material physical properties, the structure control, and power technology--to adapt itself to the recent R&D trends on new raw materials. The FY 1986 budget seeks a new office, the Office for the Enhancement of Material Designing, based on the seventh report of the Council of Aeronautcs, Electronics, Etc.

The National Institute for Research in Inorganic Materials started out in FY 1966 on the basis of the third report, "Measures for Renovating and Consolidating the Experiment and Research Organs of the Government" made by the Council of Science and Technology in July 1962. The institute has ever since been pushing R&D in order to meet all the requirements of Japan as the government research organ designed to play the central part in research on inorganic materials in Japan. In FY 1985, the institute embarked on R&D of biologically functioning ceramics and also set up a "Superhigh-Temperature Station." In FY 1986, the institute is seeking to establish a center for the exploration of unknown materials with a view to greatly stepping up its efforts to create new raw materials.

The Institute for Physical and Chemical Research, which has carried out creative and advanced research in special areas over a wide range of research fields related to physics, chemistry, and their applications, set up an International Frontier Research Organization (tentative name) in FY 1986. Its aim is to push forward advanced research. This project aims to clarify basic phenomena which provide clues to the creation of new functional materials, called frontier materials, which constitute the basis of such sectors as the S&T of information, by means of R&D of quantized elements, molecular elements, and biological elements. R&D of new raw materials has also been advanced by the Research Development Corp. of Japan which has concentrated on exploratory research of advanced technologies. These have included, since 1981, three research themes, "superfine particles," "materials of special structure," and "fine polymers." The corporation is engaged in a project for the development of new technologies. Of the results of research achieved by government research and experimental organs, etc., those which are difficult to commercialize because of the large risks involved are entrusted by the corporation to private concerns for development. In connection with the development of new raw materials, the corporation is scheduled to make contracts of commission for development of 19 items with a value of around ¥1.2 billion for FY 1986.

The collection, maintenance, and offering to the public of information on S&T related to raw materials is carried out by JICST, which was to build up a fact-data base on metallic raw materials and crystalline structures from FY 1985, and to increase its efforts in FY 1986. In addition, STA has had the Japan Atomic Energy Research Institute (JAERI), the Power Reactor and Nuclear Fuel Development Corp. (PNC), and the National Aerospace Laboratory (NAL), among others, advancing research on raw materials in their R&D of nuclear power and aerospace development.

Other ministries and agencies of the government are also pressing on with R&D. MITI, for example, is implementing R&D for measurement technology, in connection with research on "fine ceramics," "materials of film for high-efficiency separation of polymers," "materials of polymers with high electricity conduction," "materials of polymers with high facility for crystallization," "alloys with highly controlled crystallization," and "composite materials." All of these are based on MITI's R&D projects of basic technologies for future industries. MITI also is advancing research on raw materials that is expected to activate the raw materials industry, e.g., shape memory alloys and high function resins. This research is based on a law subsidizing costs for the development of technologies that serve to activate the industry. MITI also has had the Research Institute for Polymers and Textiles push R&D of various polymer materials and has had the Mechnical Engineering Laboratory, the National Chemical Laboratory for Industry, and the Electrotechnical Laboratory do the same for the development of raw materials adapted to their respective objectives.

At MOE, a subsidy for science research is being provided largely to universities to lend support to basic research on raw materials S&T. Finally, the Ship Research Institute of the Transportation Ministry, the Public Works Research Institute of the Construction Ministry, et al., are pressing ahead with research on various raw materials assessing strength and performance, among other things.

Private corporations also have active R&D underway in the fine ceramics industry and others where new raw materials are expected to support new industries. In order to translate achieved results into commercial products, a Fine Ceramics Center has been established. However, several problems still remain. For example, a system for assessment, in terms of commercialization, of new raw materials has not yet been established and this results in poor credit afforded by the user to the material offered, which results in a snag in enhancing its practical application.

Future Problems

As described above, R&D on new raw materials is being carried out vigorously in various sectors with successful results being achieved steadfastly. Nevertheless, there are problems for the future.

First, the development of raw materials in Japan has, to date, been centered on improving the performance of raw materials produced by other industrially advanced nations, and in the establishment of technologies for manufacture of

those materials at lower costs. In the coming years, however, emphasis must be placed on R&D from the basic level, including exploration and creation of new raw materials. Basic research, which has to date been pushed with the support of the fund for the coordination and enhancement of S&T, a financial aid system for exploratory research of advanced technology, etc., must be further enhanced and, at the same time, basic research of government experimental research organs needs to be stepped up to a great extent.

Secondly, in connection with research on raw materials, there are growing requirements for large-scale or highly sophisticated facilities such as those for hazardous technology and for highly analytical technologies. How to ensure funds for this equipment and how to make use of such equipment in an efficient manner are future problems.

Thirdly, interdisciplinary regions are expanding in such basic research as creation of new raw materials on the basis of biological functions. It is hoped that a flexible research system can be set up so that researchers in different fields will be able to engage themselves in joint research as the need arises. If Japan is to push forward raw material development effectively in the future, it is to be hoped that raw materials designing technology be set up firmly. Nevertheless, an increase in the data base that makes up that technology has been delayed. We must build a fully prepared data base as a major target in the course of R&D of raw materials. In R&D of raw materials, emphasis must be placed on the individual needs of the user, just as for those exploring potential useful materials. Since raw materials development requires a long time, it is important that a proper target be set up. It is also necessary to do R&D on raw materials in a comprehensive manner, because of the diversity of S&T involved. Examples include, beam technology and a variety of hazardous technologies dealing with superhigh pressure, ultrahigh vacuum, etc. A strategy or guideline is indispensable if R&D of raw materials is to be efficiently advanced in the future. It is to be hoped that a basic plan can be mapped out.

In conclusion, we should see, at long last, Japanese astronauts take part in the first raw materials experiment in a weightless environment from January 1988. Much hope is pinned on its achievements as it represents an experiment symbolic of new developments in raw materials R&D.

Worldwide Research Trends

Tokyo PUROMETEUSU in Japanese Sep-Oct 85 pp 21-25

[Article by Moriya Uchida, director of Teijin Corp.]

[Text] Industrial Revolution and Raw Materials for Advanced Technologies

Since the emergence of man on the earth, the discovery of and progress in raw materials have had tremendous effects on human communities. After the ages of stone, bronze, and iron, the advent of the industrial revolution and the invention of Watt's steam engine in 1785 permitted man application of metals as heat-resistant materials leading to prosperous operation of the iron industry.

Table 1. Major Problems in S&T of Raw Materials

Field	Major problem
1. S&T of materials and raw materials	
(1) Exploration and understanding of new phenomena related to materials	1. Creation of hazardous conditions under which to explore and clarify new phenomena 2. Exploration and understanding of new phenomena produced in the process of the formation of various substances 3. Exploration and understanding of new phenomena at the surface and interface 4. Exploration and understanding of new phenomena produced in the interaction of beams and materials
(2) Exploration and creation of new materials and new raw materials	1. Formation of new bonding concepts 2. Development of a method for the synthesis of materials based on a new reaction theory 3. Establishment of a method for the theoretical designing of raw materials 4. Synthesis of new substances and creation of new raw materials in hazardous conditions 5. Creation of new raw materials by seeking the ultimate limit in shape control and purity 6. Creation of new functions by compounding composite materials 7. Creation of new raw materials through understanding biological functions 8. Sophistication of the technologies for analysis and evaluation
2. S&T stimulating for the economy	
Development and processing of new raw materials	1. Expansion of functions of new raw materials 2. Sophistication of technologies for the application of new raw materials 3. Sophistication of technologies for the preservation and assessment of raw materials 4. Development of technologies for flawless processing and ultraprecision processing 5. Development of new technologies for processing and treatment based on beam technologies
3. Every activity related to raw materials S&T	Development and full application of machines and equipment for use in the assessment of raw materials and in the creation of hazardous conditions.

Source: Abstract from the 11th report of S&T Council

Table 2. S&T Made by the STA for FY 1986 (¥1 million)

Item	Budget for FY 1985	Budgetary request for FY 1986	Reference
1. National Research Institute for Metals	3,833	(bond) 614 4,096	1. Implementation of special research on the technology of metal materials 176 (174) (1) "Intermediate compounds used as high-performance light-emitting devices" 36 (0) (2) "Raw materials for machines and equipment to be subjected to ultralow temperatures" and three other items 140 (174) 2. Construction of a laboratory for experimentation on the control of surface and interface of metal (bond) 614 238 (0) 3. Organizational structure: institution of the Office for the Enhancement of Materials Designing (Research Section on the Property of Materials)
2. National Institute for Research on Inorganic Materials	1,766	(bond) 592 1,775	1. Enhancement of special research on inorganic materials 95 (95) (1) Modification of diamonds into semi-conditors 40 (0) (2) Materials super resistant to abrasion 26 (0) (3) Biologically functioning ceramics 29 (50) 2. Construction of a special laboratory for experiments on vibration free states (bond) 592 177 (0) 3. Organizational structure institution of a Center for the Exploration of Unknown Materials
3. Institute for Physical and Chemical Research	0	(bond) 1,133 647	1. R&D of "frontier" elementary devices 300 (0) 2. Construction of a Central Raw Material Laboratory (bond)1,133 347 (0)
4. Research Development Corp. of Japan	1,011	559	Enhancement of research via the system of exploratory research of advanced technology (1) Superfine particles 191 (349) (2) Materials of special structure 251 (415) (3) Fine polymers 137 (247)
5. Enhancement of R&D based on "Fund for Coordination and Enhancement of S&T"	1,900	2,100	(estimated appropriation) Six items continuing from the foregoing years --Electro superconductivity and ultralow temperatures (82-86) --Technology for assessment of credibility of structural materials (83-87) --Hybrid materials (84-88) --Lasers of high power and variable frequency (85-88) --Technologies involving ultrahigh temperatures (86-89 --Creation of new materials by means of weightlessness(82-86) One or two new items are slated to begin this year
Total	8,510	(bond) 2,339 9,177	107.8 percent
Items related to raw materials S&T 1. Japan Center for Information on S&T	73	233	(government special account for investment in industry) 1. Fact data base 57 (13) (1) Crystalline structure data base 23 (6) (2) Metallic materials data base 33 (7) 2. Literature data base 167 (60)
2. Research Development Corp. of Japan	1,127	1,247	(estimated value of contracts for commissioning of developmental research) 19 items including a technology for lowpressure vapor phase synthesis of diamond films
3. Japan Atomic Energy Research Institute	0	(bond) 1,870 200	Research on radiation by means of high technology Construction of equipment for the irradiation of ions of high energy
(subtotal)	1,200	(bond) 1,870 1,670	Total expenditures for S&T of raw materials including related items (bond) 4,209 10,846 (9,710) 111.7 percent

System for the Enhancement of Research on Raw Materials in Japan

- Prime Minister's Office
  - Council of Science and Technology
  - S&T Agency
    - Bureau of Research Coordination
      - General Research Division: general enhancement and coordination of S&T for raw materials
      - Office for Enhancement of Development of Raw Materials: enhancement of development of new raw materials based on Fund for Enhancement and Coordination of S&T
    - National Institute for Research on Inorganic Materials
    - National Research Institute for Metals
    - National Aerospace Laboratory (development of raw materials for use in aeronautics)
    - Institute for Physical and Chemical Research (basic research)
    - Research Development Corp. of Japan (promotion of development of new raw materials via the system of exploratory research of advanced technology)
    - Japan Atomic Energy Research Institute (development of raw materials for use in nuclear power generation)
    - Power Reactor and Nuclear Fuel Development Corp. (development of raw materials for use in nuclear power generation)
    - National Space Development Corp. (development of raw materials for use in space)
    - Oceanic S&T Center (development of raw materials for use in oceans)
    - Japan Information Center of S&T (building data base for development of raw materials)
  - National Police Agency — National Research Institute of Police Science
  - Agency for Development of Hokkaido — Bureau for Development of Hokkaido — Public Works Experiment Station [Hokkaido]
- Ministry of Agriculture, Forestry, and Fisheries — Agricultural Civil Engineering Research Station
- MITI — Agency of Industrial S&T (implementation of new raw materials development based on the R&D Project of Basic Technology for Future Industries, etc.)
  - Research Institute for Textiles and Polymers
  - Electrotechnical Laboratory
  - National Chemical Laboratory for Industry
  - Mechanical Engineering Laboratory
  - All government industrial research institutes in local districts
- Ministry of Transportation
  - Ship Research Institute
  - Port and Harbor Research Institute
- Ministry of Labor — Industrial Safety Institute
- Ministry of Construction
  - Public Works Institute
  - Buildings Research Institute
- Ministry of Education — Universities (academic research on S&T of raw materials)

Note: This table is a list of research and experimental organs engaged in R&D related to raw materials.

Progress in the steam engine subsequently resulted in the development of transportation facilities and growing trade with colonial countries. The attractive trade in dyes, in turn, was challenged by the invention of synthetic dyes, which paved the way for the arrival of the age of the organic chemical industry. This lent itself to the development of coal chemistry and electrochemistry, which, coupled with the polymer theory put forward in 1927 by Dr Staudinger, finally led to polymer and petroleum chemistry.

Progress in the development of metals, meanwhile, brought the internal combustion engine. In 1910, an invention by Ford of a method for mass production automobiles, marked the start of a mass consumption society in the world. Progress in the automobile industry provided a social basis for the development of the airplane. Invention of aluminum alloys led to the materialization of mass transportation airplanes. Progress in the airplane industry, in turn, created a social basis for the development of rockets, and heat-resistant materials by various types have made the exploration of space possible.

In the sectors of electricity and magnetism, an era of vacuum tubes using nickel and tungsten as major raw materials was followed by transistors using germanium and silicon. These, coupled with super fine processing technology using photosensitive resins, etc., has led to the invention of integrated circuits (IC), large-scale IC's (LSI), and very large-scale IC's (VLSI). This has permitted the emergence of a civilization based on electronics.

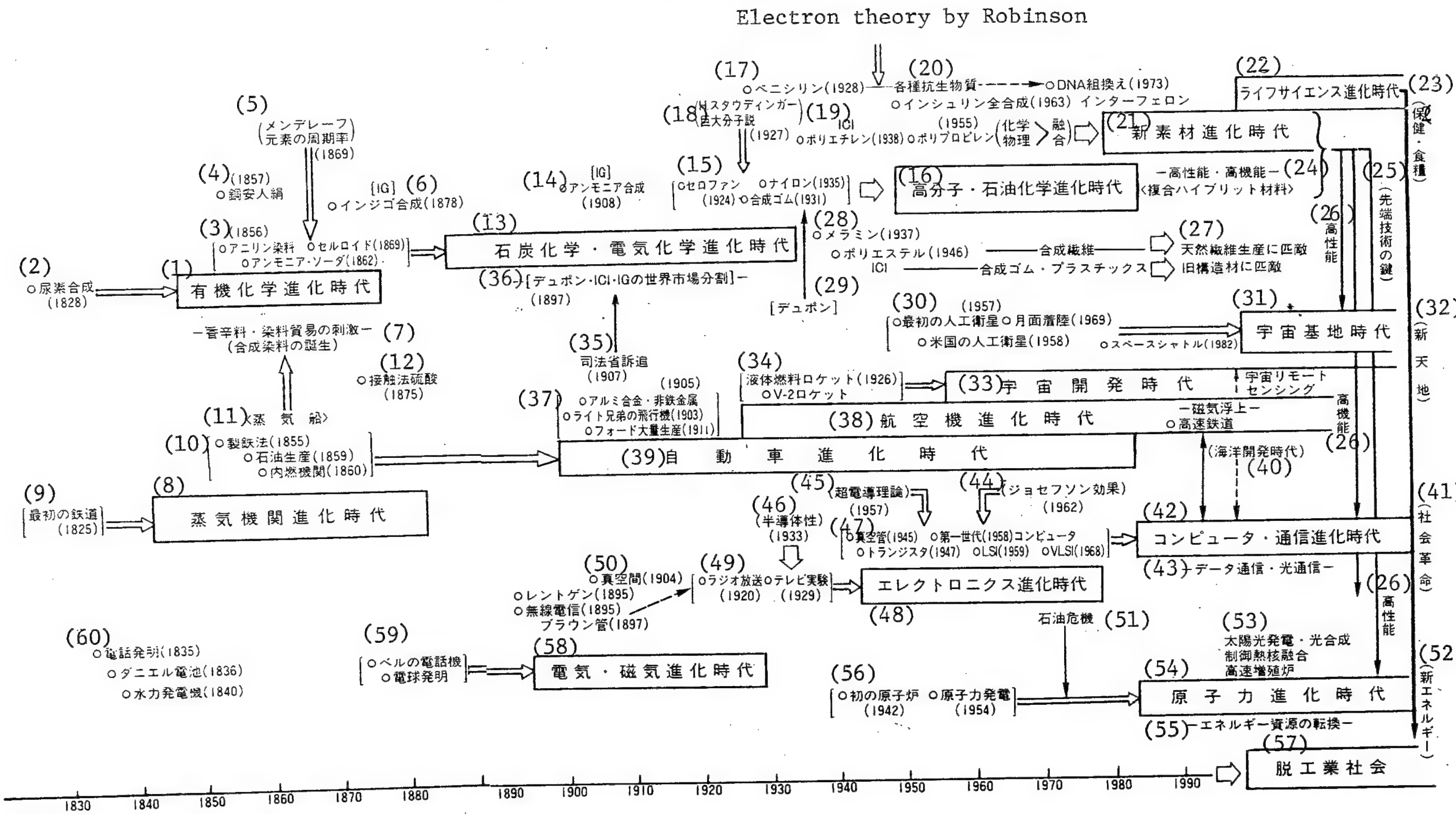
In the energy sector, we have seen nuclear power generation blossom into scientific and industrial success by making use of special properties of certain materials, for example, enrichment of uranium and shielding of radioactivity. As can be seen, an invention of advanced raw materials and application of that material to the needs of society have been economically successful, providing the invention proved adaptable to the problems posed by the industrial society. In other words, new advanced raw materials provide the clue to industrial innovation. This situation is presented diagrammatically on the next page.

The 1980's is an unprecedented decade in that steel has become equivalent to plastics in production around the world, just as natural fibers are to man-made fibers. With the development of a petroleum civilization, synthetic raw materials having achieved quantitative expansion, are on the market together with conventional materials. Against the background of global social upheaval triggered by the oil crises, R&D of advanced raw materials must be selected and transformed on the basis of developed S&T, in a manner such that the prosperity of mankind will be best served.

Progress and Development of Raw Material Science

An advanced raw material is characterized by the discovery of new functions and performance therein and the development of relevant applications with consequent impacts on industries, and not by a mere replacing of conventional ones and by a subsequent quantitative expansion.

Figure. Industrial Activity and Advanced Raw Materials



Source: "International Strategy for Technology Based on Industrial Properties" written by Seiya Uchida and published in 1985 by the Yohikaku Corpo.

Key:

1. Era of progress in organic chemistry
2. Synthesis of area (1828)
3. Aniline dyes (1856)
   Ammonia soda (1862)
   Celluloid (1869)
4. Cupro-ammonium rayon (1857)
5. Mendeleeve: period table of elements (1869)
6. Synthesis of indigo (1878)
7. Incentive from trade of spices and dyes--emergence of aniline dyes
8. Era of progress in steam engine
9. First railway in history (1825)
10. Method of iron manufacture (1855)
    Production of petroleum (1859)
    Internal combustion engine (1860)
11. Steamship
12. Sulfuric acid through contact process (1875)
13. Era of progress in coal chemistry and electrochemistry
14. Ammonia synthesis (1908)
15. Cellophane (1924)
    Synthetic rubber (1931)
    Nylon (1935)
16. Era of progress in chemistry of polymers and petroleum
17. Penicillin (1928)
18. Giant molecule theory of H. Staudinger (1927)
19. Polyethylene (1938)
    Polypropylene (1955)
    Merger of physics and chemistry
20. Various antibiotics
    Total synthesis of insulin
    DNA-recombination
    Interferon
21. Era of progress in new raw materials
22. Era of progress in life sciences
23. Health and food
24. High performance, high function--composite hybrid materials
25. Keys to advanced technologies
26. High performance
27. Compare with natural fibers in production
    Compare with conventional structural materials
28. Melamine (1937)
    Polyester (1946)
    Synthetic rubber, plastics
    Synthetic fibers
29. DuPont
30. First artificial satellite (1957)
    Artificial satellite of the United States (1958)
    Landing on the moon (1969)
    Space shuttle (1982)
31. Era of space bases
32. New horizons
33. Era of space development; remote sensing of space; remote sensing of universe
34. Liquid fuel rockets (1926)
    V-2 rockets
35. Justice Ministry indicting (1907)
36. Division of the workd market by DuPont, ICI, and IG
37. Aluminum alloys, nonferrous alloys (1905)
    Airplane flown by Wright brothers (1903)
    Quantity production by Ford (1911)
38. Era of progress in airplanes
    High-speed railway--linear motor cars
39. Era of progress in automobiles
40. Era of ocean development
41. Social revolutions
42. Era of progress in computers and communications
43. Data communications, optical communications
44. Josephson effect (1962)
45. Superconductivity theory (1957)
46. Semiconductors (1933)
47. Vacuum tubes (1945)
    Transistors (1947)
    Computer of first generation (1958
    LSI (1959); VLSI (1968)
48. Era of progress in electronics
49. Radio broadcasting (1920)
    Television experiment (1929)
50. Vacuum space (1904); Roentgen (1895)
    Wireless telegraphy (1895)
    Braum tube (1897)
51. Oil crises
52. New energies
53. Solar power generation, photosynthesis
    Controlled thermonuclear fusion
    Fast breeder reactor
54. Era of progress in nuclear power
55. Conversion of energy resources
56. First nuclear reactor (1942)
    Nuclear power generation (1954)
57. Deindustrialization of society
58. Era of progress in electricity and magnetism
59. Telephone invented by Bell
    Invention of the lightbulb
60. Invention of telephone (1835)
    Daniel cell (1836)
    Hydraulic electric power generator (1840)

Mutual approach of physics and chemistry of recent years has led to the understanding of raw materials as the activity of electrons, atoms, and molecules. Progress in electronics has permitted one to understand a chemical reaction as movements of electrons, while development of measurement technology and of machines and equipment has led to development of a computer chemistry which permits the analysis and control of the movement involved. There has arisen, therefore, the possibility that the atomic and molecular structures and properties of a raw material produced may be understood also as a result of movements of electrons.

In metallic elements, for example, electronic structures of atoms and their crystalline structures have been clarified, and their relationship to relevant physical properties has been understood. Technologies for molding and processing to control these structures and to bring out intended properties have also been emerging through high industrial technologies. One example is designing and creation of new raw materials using excitation beams, which are capable of controlling interconversion between gaseous and liquid phases of an element, electronic conditions, processes, and interface conditions. This permits new functions to manifest themselves. Also included are new manufacturing processes under hazardous conditions, manufacture of amorphous structures of metals through rapid quenching and solidification processes, and the manufacture of alloys by mechanical force using superfine metal particles.

Parallel with the advance of S&T for designing molecules, for aggregates of atoms and molecules, for processes of formation or manufacture, there must be scientific progress on the mechanism of interaction between atoms and between molecules, and microscopic analysis of interface function, both of which lend themselves to understanding the mechanism for the manifestation of new functions. In consequence, one can expect that in the 21st century, the designing and creation of agglomerates of atoms and molecules will be feasible for the following materials: materials displaying some specific functions, those with functions under hazardous conditions, those with electric superconductivity or high dielectric properties, etc. Additionally, materials exhibiting high degrees of response to electric, optical, magnetic, thermal, or chemical effects; materials in film form that manifest a high degree of functions for recognizing molecules and separating them; materials with biological adaptability or with functions simulating those of life. This implies that the science of raw materials, which has made rapid advances in recent years, is creating the possibility of a new raw materials industry which uses atoms and molecules as resources.

The Western nations of advanced technology, therefore, have begun to invest in research on raw materials on a long-term basis, and to provide for systematic research. They also hope to bring out a system of engineering by which to translate scientific knowledge into industry and to have it blossom into commercial products. Particular importance is attached at this juncture to the training of expert scientists and technicians in these sophisticated sciences and technologies. Policies are being implemented on the assumption that this training, coupled with an appropriate investment in R&D alone can make the project successful.

Basic Research on Advanced Raw Materials in the United States

The United States is leading the world in research on advanced raw materials. The research depends largely on budgetary appropriations of the government made on the national security grounds. The Defense Ministry has had the Technical Research and Development Institute (TRDI) comprehensively plan and manage the Advanced Material R&D Program, while NASA is implementing the Aircraft Energy Efficient Program with R&D largely centered on composite materials moving ahead.

Where the Energy Ministry is concerned, the Raw Materials Division, affiliated with the Energy Research Bureau which advances comprehensive R&D, is implementing a materials science program. In this program, the division comprehensively manages research on raw materials which are carried out by each laboratory of the ministry and by those outside of the ministry under commission contracts. Worthy of special note is the establishment of the Center for Raw Materials in the Lawrence Berkeley National Research Institute. The institute, which is managed by the University of California and excels in nuclear physics, has selected raw materials science instead of nuclear physics, believing that its future depends on the development of the former. Allowing for energy radiation technology and technologies for heat-resistant materials, which the institute has long been involved in, and considering long-term research, the institute has set up the following research program and research element themes as the basis of its research which is centered in the advanced cyclotron light source: 1) electronic materials and materials for advanced semiconductors and electronic devices; 2) structural materials and processing of advanced heat resistant ceramicsfor structural use, structural polymer materials, modeling of manufacturing processes for structural composite materials, structural alloys, and computer-aided design (CAD); 3) interface science and catalysts, advanced methods of measurement for surface sciences, catalysts, and uniform catalyst metal clusters. The projected budget for the basic facilities for 5 years is $150 million. The budget for FY 1983 is $2.3 million and after completion of the facilities, $15 million.

The Department of Commerce has had the National Bureau of Standards put together a method of assessment of raw materials and relevant data bank systems. It is noteworthy that the Center for Material Sciences separated from the National Measurement Laboratory in 1983 to become an independent organ. The center comprised 325 research members and 120 guest researchers and started with a budget of $25 million. With research limited to advanced raw materials of metals, ceramics, and polymers, its four subjects, i.e., raw materials processing, determination of fine structures, physical properties, and assessment of performance are studied synthetically with a view to establishing information on basic technologies. In the determination of fine structures of raw materials, an important role is being played by nondestructive methods for equipment for small angle scattering of neutrons and those using the cyclotron, which have contributed greatly to the progress of nuclear physics. Among the subjects being studied are the fine structure of new ceramics and details of defects development, transition state oversaturated

metals, molecular structures and conformations of polymer blends. This research is being implemented by active cooperation among academic associations in the entire United States. Measurement of data associated with the phase diagram and collection and publication have been accomplished for alloys and ceramics since 1933, and for oxides, carbides, nitrides, borides, semiconductors, etc., this started in 1983, marking its 50th year, intending to continue for the next 50 years. The budget was $709,000 with that for 1987 projected at $3,335,000.

Application of Advanced Raw Materials According to World's Demand

a) Advanced Raw Materials Related to Energy

Parallel with conversion to alternative energies since the oil crises, we have seen development to raise efficiency in generation of raw materials resistant to high pressures and high temperatures for use in gas turbines. That is, we have seen heat resistant alloys, nickel based or cobalt based; heat insulation coating; fiber-reinforced metals; W-fiber-FE, Cr, Al, Y-composite materials; ceramics of high heat resistance and great strength; and fiber-reinforced ceramics; among other things. Where materials for nuclear power generation are concerned, major problems include improving Ni-based alloys, stainless steel, and elements of low cobalt content. As for the fast breeder reactor, a new raw material is sought that can withstand corrosion by coolant sodium at temperatures as high as 500°C. Raw materials associated with the nuclear fusion reactor, though a subject for future study, involve the development of superconductive materials and magnets. The former may conceivably be applied to MHD power generation and the linear motor car in addition to nuclear fusion. Elements constituting superconductive materials fall largely into the rare metals group, with the alloys Nb-Zr and Nb-Ti, and intermetallic compounds Nb-Sn and V-Ga, among others, being the most promising.

Also in development are polycrystal and amorphous silicon in connection with solar cells for power generation; an alkali resistant, hydrothermally resistant, anticorrosive material in connection with geothermal power generation; strong, lightweight composite materials in connection with the utilization of wind power.

Of industries consuming large quantities of energy, steel and cement have been freed from petroleum consumption whereas the chemical industry still remains heavily dependent on petroleum. This industry uses 60 percent of its total spent energy in separation and purification of substances such as crystallization and distillation. This has induced the industry to make R&D on separation film based on the difference of physical properties of molecules. Some of the enormously wideranging applications of the film are: preparation of desalinated water from sea water, concentration and separation of ethyl alcohol from diluted solutions of alcohol derived from biomass, production of ultrapure water for use in electronics, concentration of foods that suffer disintegration at high temperatures, etc. Where gas separation is concerned, application of concentrated oxygen for the improvement of combustion efficiency, application of films for decontamination of environments, for medical purposes, and for concentration of special gases, such as helium.

Where conservation of energy for transportation is concerned, research is advancing on materials for automobiles weighing less than steel, materials reducing tire resistance, heat resistant materials for engine components in order to reduce energy losses due to cooling, turbo-engines, and ceramic engines. The United States places emphasis on silicon nitride and silicon carbide as materials for ceramic engines. The United States is pushing forward R&D believing that chrome is barely available in the free world. Chrome is used both in an alloy which is resistant to temperatures of 1,000-1,300°C and of high strength, and in high chrome superstainless steel of great resistance to corrosion making it an important strategic material. A substitute material is a necessity for the United States.

b) Advanced Raw Materials Related to Airplanes

Since 1975, NASA has had an Aircraft Energy Efficient Program, aimed at cutting back airplane fuel consumption by more than 50 percent. Where raw materials are concerned, development is underway for composite materials of great strength for use in thin short blades turning around at supersonic speeds in the turboprop engine. This R&D on primary structural materials is for reduction of weight. In the latter, the predominant role is played by an organic composite material, which is based on epoxide resin reinforced by both a high strength carbon fiber against compression and an aramide fiber of high tensile strength. The material has found applications in commercial planes, including those of the Boeing Corp. Application of composite materials in the structural materials of airplanes is advancing rapidly for military uses, with the VTOL Douglas AV-8B aiming at a weight reduction of around 8 percent by using 1,299 pounds of composite materials, and a future fighter plane, ATF, aiming at a 15 percent reduction by using 4,300 pounds of materials. Military supersonic jet planes have their aluminum alloys replaced by organic composite materials and their steel and titanium by a boron fiber-reinforced epoxide resin. S-75 helicopters, trial-manufactured by Sikorsky Aircraft Corp., are made of 36.9 percent graphite, 17.9 percent aramide, 11.5 percent aluminum, 5.6 percent steel, 5.3 percent glass and plastics window panes, 20.9 percent adhesives, foams, etc., and 1.9 percent glass fiber, severely limiting the metal composition.

The frame of the private business plane, AVTER-400, completely made of composite materials, has 21 percent high strength glass and carbon fiber, and 79 percent high strength aramide fiber as a reinforcement. It is molded from normex honeycomb and a special epoxide resin. The AVTEK-400 has a load-weight ratio twice that of the conventional turboprop planes, a takeoff distance of 1,250 feet, half the normal, a climbing speed of twice and fuel costs of a third to a half that of conventional planes, and a cruising speed of 425 miles per hour, which is reputed to be the fastest.

c) Advanced Raw Materials to Space Development

Heat resistant materials have contributed greatly to the success of space development. The temperature of the external wall of a space shuttle, after it is launched from the earth, travels through outer space, reenters the atmosphere and returns to the ground, ranges from minus 170°F in outer space

to 2,300°F during the period of reentry. The tiles of the external wall must be designed such that the temperature of the aluminum alloy of the internal wall does not rise beyond 350°F as the shuttle endures space temperatures of minus 170°F and a heat pulse of 2,000 seconds at the time of reentry. A tile produced by Lockheed Corp. using boron fusion of silica fiber Nextel 312 made by the 3M Corp., displayed a dramatically improved performance in weight based strength and toughness. Lockheed, further applied to the tile a reaction cured glass coating in order to improve its heat resistance and obtained a product with a surface hardness equivalent to that of a diamond even at test temperatures of 2,300°F. It can even withstand temperatures of 3,000°F.

Composite materials involving the filament winding of carbon fiber and epoxy resin have good prospects of being used as structural materials in the construction of a space station, together with aluminum alloys, etc. Success in space development has permitted space satellite communications which, coupled with optical communications form a cornerstone of information innovation. Another hope pinned on space development is related to the production of new raw materials in a space factory. Parallel with progress in optical electronics, compound semiconductors such as the amorphous Si-As-Te series and the single crystal Pb-Sn-Te series play an important role as raw materials for laser oscillator devices and as photo detectors. Nevertheless, large differences in specific gravity among relevant component elements prevent consistency of the product from being homogeneous on the earth, and products of high purity are very difficult to obtain here. On the other hand, the attempt has proved successful in space experiments. In addition, a composite Ni-TiC alloy produced in space has a hardness approximately 2.6 times that of the space alloy produced on the earth. It also is resistant to a temperature of 1,100°C, a property superior to all others. The alloy has uses in airplane turbine blades among other things.

From 1987, the "International Microgravity Laboratory, or IMC Program," will begin. This is a space experiment using the space shuttle at low cost and implemented jointly by rations of the world. From 1991, construction of a space station is slated to begin, with a full-fledged space station materializing by the year 2000.

Quantum Effect Elementary Devices

Tokyo PUROMETEUSU in Japanese Sep-Oct 85 pp 26-27

[Article by Yoshinobu Aoyagi, deputy chief researcher of the Laser Science Research Group, the Institute of Physical and Chemical Research]

[Text] Raw materials for semiconductor elements are presently limited almost exclusively to the silicon and gallium arsenide series. One may well wonder why such an extremely limited number, of all the variety of inorganic raw materials, is available for practical application. This may either be due to the fact that our technology level is not sufficiently high for making use of other materials, or that the other materials lack, in various aspects, required qualities. Researchers have developed elementary devices by

making the best of the properties of the raw materials afforded by nature. Performance of elementary devices has been largely dictated by properties of raw materials. The electron mobility of silicon, for example, is around 1,500 cm^2/VS, which imposes limitations on the use of this material in connection with its use as a high-speed element for LSI's. Research on the LSI of gallium arsenide, the electron mobility of which is around five times that of silicon, is currently underway. Gallium arsenide (GaAs), through heterojunction with aluminum GaAs (AlGaAs), has made a high efficiency laser successfully. The wavelength of the oscillated laser, nevertheless, is limited in the infrared and red regions exclusively. Both the band structure, associated with the oscillated laser wavelength, and the electron mobility referred to above, account for the basic properties of the raw materials and are not amenable to artificial modification except in special conditions such as superhigh pressure. However, a concept has recently been developed, which is being seriously considered. It is that the basic properties of raw materials for the device must be modified in such a way that any material required for an elementary device can be designed, rather than designing the device according to the properties of the specific material. The quantum leap forward for raw materials for elementary devices, which is set forth below, is where one raw material permits the designing of materials for elementary devices. The technology of making this material provides raw materials for elementary devices and properties which have not so far been available to the industry. This permits an artificial control of the basic properties of these materials.

Featured Materials for High-speed Logic Elements and for High Efficiency Light Emitting Elements

In crystal, atoms arrange themselves in an orderly manner and periodically build up varying potential energy with respect to electrons adapted to the regular arrangement of the atoms. This determines the effective mass and band structures for the electrons in the crystal.

If this periodically varying structure is introduced in a crystal in some way artificially, the electrons become affected by this periodical potential artificially produced as well as by that due to the atoms of the crystal. This leads to different electron behavior.

Consider a few scores of layers of GaAs and the same number of layers of AlGaAs stacked one upon another. Since the width of the forbidden band of GaAs is substantially smaller than that of AlAs, a potential well is produced which causes the complex material above to stop exhibiting its bulk properties and to behave as a quantum effect involved material for elementary devices. This occurs providing the width of the well is below approximately 100 angstroms, i.e, narrow enough to produce the so-called quantum effect. The quantum effect here means that electrons have scattered energy values and, consequently, the density of state and the energy structure of electrons varies, in large measure, with the width and depth of the well and with the interaction of the well with neighboring ones as compared with those of the bulk. If the potential barrier is narrow enough to permit a tunnel effect of electrons, the electrons no longer localize in a single well, but

disperse to each and every well. This forms a miniband. The material has the effective mass of the electrons changed by this miniband, and exhibits negative resistance, under certain conditions, to the current flowing vertically to the well.

It has been proved also that direct transition type materials are sometimes converted to indirect transition types or vice versa by reducing the width of the potential well and the potential barrier to a single or several layers of atoms. Where there is no interaction among potential wells, the electrons shut up in a well behave as secondary electrons. This leads to a change in the density state of the electrons and to growth of the band energy of excitons, which become stable even at room temperatures. The probability of recombination of these secondary electrons and excitons is high, permitting laser diodes with high efficiency in oscillation to be brought out. It becomes possible, furthermore, to attain high electron mobility of 200,000 cm^2/VS or more at liquid nitrogen temperatures even without changing high electron density by modulation doping, which separates the region of impurity doping from the one where carriers are mobile.

MBE Method and MDCVD Method

At present the method for the manufacture of these materials falls largely into two types: the molecular beam epitaxial growth method, MBE, and the method of gas phase epitaxial growth, MDCVD, for organic metals. The external appearance of MDCVD equipment developed by this research institute is presented in the photograph [omitted]. The MBE method involves deposition, layer by layer, of constituent atoms of single-atom thickness on a base plate in a superhigh vacuum space. It permits areation of heterojunctions and doping of impurities by changing the kind of atoms to be gasified and deposited. In the MDCVD method, an organic metal compound is pyrolyzed in an oven and the resulting compound atoms produced are deposited on a base plate. Control of layers of single atom thickness has recently been made possible. Both methods have advantages and disadvantages. The MBE method, conceivably, permits direct observation of crystal growth and easy control of the thickness of depositions. The MDCVD method does not necessarily require vacuum space as high as MBE, and hence may be favorable for practical application. Neither is totally superior. Either may be used, depending upon individual objectives.

Though presently moving forward with raw materials of the GaAs series, development of the quantum effect involving raw materials for elementary devices will be attempted using materials other than the GaAs series in the near future, and new data will be gathered on their properties.

The author has described cases where electrons are quantized in most cases, exclusively. It may be possible, however, to bring out a quantum effect for new materials for elementary devices as quantum lines or quantum boxes if electrons are shut up, in some secondary or tertiary fashion. This concept is still under consideration, with a few suggestions having been made and a variety of attempts just getting underway. Nevertheless, in the event quantum lines and quantum boxes are realized, the behavior of electrons must differ greatly from those in bulk or in primarily quantized materials. Where the

state of density, for example, is concerned, it will become possible to realize an electron system which is completely localized at a certain energy value.

The quantum effect on raw materials for elementary devices described above has made it possible to artificially create cut raw materials with new properties by selecting appropriately the component materials, the width of the potential well and that of potential barriers. This is the case, not only with raw materials for semiconductors but also with those for metals and organic compounds.

It is intriguing that basic properties of raw materials, which have been out of man's control to date, can be under his control by virtue of the development of "nanometer engineering." This tries to control the microscopic region below the level of one nanometer by artificial means. This, at the same time as life, is coming under the control of man by virtue of the development of gene engineering, which controls the microscopic world of the gene.

New Ceramics

Tokyo PUROMETEUSU in Japanese Sep-Oct 85 pp 28-29

[Article by Takeshi Kikuchi, chief researcher, Planning Division, National Institute of Research for Inorganic Materials, STA]

[Text] The term "fine ceramics" or "new ceramics" has recently been used frequently. In a document requesting the establishment of this institute, submitted in 1963, the author found this term along with a statement of its importance and could not but be impressed by the excellent viewpoint of the pioneers given the present prosperity of the new ceramics industry.

Since its establishment in 1966, the National Institute of Research for Inorganic Materials has been engaged in research on inorganic materials, upon which much hope had been pinned for applications, with a view to creating superhigh purity products. The institute further hoped to make a characterization of materials (i.e., determination of composition, organization, and structure), study physical properties, and understand special properties. Not all the materials studied have developed into new raw materials, of course, but knowledge and technological information built up in the course of these investigations have been effectively used in creating new raw materials.

For example, this institute has recently developed a technology for the growth of crystals, called the floating zone method. This permits growth of single high quality crystals in connection with the yttrium iron garnet, YIG, invented by the Bell Telephone Laboratory of the United States in 1955. Countries around the world have noted the excellent quality of multiple mode optical fiber isolators, a microwave filter that uses this material. It is evident, even from this single example, that it takes a long period of time between discovery of a useful material and a new raw material which has a

practical application through R&D. Such a discovery can lead to extended effects which are not even dreamt of initially. The table presents a list of research items on new ceramics which the institute has carried out and the technologies which the institute has transferred to private corporations through the Research Development Corp. of Japan. Some of the new raw materials devised by the institute are presented below.

Table. Patented Research Subjects Related to Fine Ceramics, etc., for the National Institute of Research on Inorganic Materials

Number	Subject of research
1.	Method of manufacture of titanates of alkali metals in fiber form
2.	Technology for the manufacture of a thermal electron emitting cathode of lantanum boride
3.	Technology for the manufacture of magnetic resonance elements using single crystals of the garnet type
4.	Method of manufacture of single crystal of magnesium titanate
5.	Method of manufacture of an opal-like substance
6.	Technology for polychromic treatment of oxide film on an aluminum anode
7.	Method of manufacture of titanates of alkali metals in fiber form, II
8.	Method of manufacture of boron nitride in cubic form
9.	Method of manufacture of sintered bodies of silicon carbide
10.	Method of manufacture of glass of a composition with a low melting point and low thermal coefficient of expansion
11.	Method for purification of beryllium compounds
12.	Aluminosilicate glass
13.	Method for molding porous apatite
14.	Method of manufacture for high-quality boron nitride in cubic form
15.	Method of manufacture for the sintered body of Sialon
16.	Method for growing single crystals of inorganic composite oxide
17.	Method of manufacture of sintered bodies of high-purity diamond
18.	Method of manufacture of silicon nitride by means of gas pressure sintering
19.	Method of manufacture of sintered bodies of high-purity boron nitride in cubic form
20.	Aluminosilicate glass resistant to heat
21.	Glaze compositions
22.	Polychromic coloring of metal surfaces
23.	Method of manufacture of alkali titanate in fiber form, III
24.	Technology for synthesis of diamond film by gas phase reaction at low pressures
25.	Technology for the synthesis of diamond film by a gas phase reaction at low pressure, II
26.	Method of manufacture, by fusion, of titanate fiber
27.	Method of setting cement of the apatite type
28.	Method of manufacture of an alumina which is colored but transparent
29.	Method of manufacture of sintered bodies of silicon carbide
30.	Method of manufacture of sintered bodies of silicon carbide, II
31.	Method of manufacture for single crystals of magnesium titanate
32.	Method of manufacture for β-silicon carbide

Fiber of Potassium Titanates

Potassium titanates fiber represents a group of compounds with the general formula $K_2O \cdot nTiO_2$. Compounds of this formula, where n denotes 1, 2, 4, 6, or 8, are presently known and, of these, those with n standing for 2, 4, and 6 have better prospects as industrial raw materials. Potassium dititanate and potassium tetratitanate have a layer structure and potassium hexatitanate a tunnel structure. Specific properties of the raw materials are dictated largely by this difference in types.

The mistake has developed a method involving, first, growing a long potassium tetratitanate fiber using a flux method, and then subjecting the fiber to a secondary treatment which converts the potassium tetratitanate into potassium hexatitanate while the fiber remains unaltered in form. Fiber obtained from potassium tetratitanate fiber by washing out all potassium present in the interlayer spaces of the fiber and by substituting hydrogen for the potassium relinquished has excellent properties as a cationic ion-exchange material. Various other methods of application are now under investigation. These include treatment of radioactive waste water, recovery of very small amounts of useful metals, and catalysts. Potassium hexatitanate fiber, meanwhile, has a wide range of applications. As a structural material, it is used for reinforcement (plastics, cement, etc.), as heat insulation materials (sheet, coating material, paint, etc.), electric insulation materials (coating of electric wire, paper, etc.), friction materials (brake lining) and so on. As for functional materials, the fiber is put to use as a separation material (diaphragm of alkali cell, medicine, filter for drinks, etc.).

Single Crystals of Lanthanum Boride and Titanium Carbide

The single crystal of lanthanum boride (LaB_6), an excellent material for radiation of high-density thermal electrons, gives an electron beam of longer life and stabler, higher luminance than does old sintered lanthanum boride. The crystal is used as standard equipment for the electron microscope of today by almost all Japanese makers. This single crystal is also used practically, in large measure, as the cathode in pattern imprinting equipment for super LSI's. Because of the request for a raw material of higher stability and luminance in connection with imprinting chips of over four megabits, expected to become available in the near future, the institute has developed the single crystal of titanium carbide, TiC. It is a raw material of the cold cathode electric field radiaton type and has definitely proved to have a performance superior to that of lanthanum boride. Research is now advancing for its practical application. It is also expected that an analytical electron microscope of lower color aberration and an electron microscope of higher resolution may result from the use of this material.

Sintered Body of α-Sialon

α-Sialon involves a structure of silicon nitride in which yttrium, aluminum, and nitrogen are dissolved in a solid solution. It is produced by subjecting a mixture of silicon nitride powder (Si_3N_4), yttrium oxide (Y_2O_3), and aluminum nitride to sintering in a nitrogen stream. The discovery of Sialon

was made by the institute and a British organization simultaneously, but independently of each other. α-Sialon, along with the β-Sialon which had been known prior to the former and which is a solid solution of β-silicon nitride structure, may conceivably find applications in cutting tools, in engine components, and heat-resistant rollers because of its high strength, toughness, and high resistance to abrasion.

Gas Phase (CVD) Grown Diamond Films

Diamond excels in resistance to abrasion and in heat radiation. Though it had been regarded as impossible to artificially create diamonds except under superhigh pressures and high temperatures, the institute, following the Soviet Union, successfully deposited diamond on a silicon base plate in 1982 using the hot-filament CVD (gas phase synthesis) method, where a methane gas of below 1 atm is diluted with hydrogen. The diamond was also prepared later through plasma CVD, etc., using microwave excitation. Extended effects of this technology are expected to be extensive. Not only is the substance being developed into cutting tools by some corporations, but developmental research is now underway for its use as a heat-releasing base plate in semiconductors. Moreover, research for the synthesis of a diamond semiconductor in film form is underway in the institute. It is expected that an entirely new semiconductor, capable of functioning at higher temperatures than conventional semiconductors will be created.

Glass of La-Si-O-N (lasion) Series

Glass, made under nitrogen atmosphere and under pressure using nitrides such as silicon nitride and aluminum nitride together with oxide as the raw material, tends to exhibit increasing improvements in mechanical properties such as hardness, Young's modulus, and declining coefficient of thermal expansion with increasing nitrogen content. The institute has succeeded in bringing out a glass, the hardest ever reported, by means of synthesis of glass of the La-Si-O-N series. This glass has a hardness twice that of common glass for windowpanes and is expected to find applications in high pressure vessels and in windowpanes of airplanes. Use is also possible in high strength composite materials by turning the glass into fiber.

When the author reviews the process of research that has achieved notable results to date, he cannot but feel the importance, in fine ceramics, of interdisciplinary research and basic, groundbreaking research. If Japan is to take the lead in this research in the future, it must stress creation of numerous and entirely new raw materials through understanding the physical properties and functions of useful new substances.

New Materials From Rare Metals

Tokyo PUROMETEUSU in Japanese Sep-Oct 85 pp 30-31

[Article by Shiro Yoshimatsu, director, Refining Research Department, National Research Institute for Metals, and Yoshisuke Hasegawa, chief, Second Nonferrous Research Office of the same institute]

[Text] The intimate relationship between rare metals and functional materials is well known, e.g., between silicon and semiconductors, between gallium and light emitting elements, between niobium and superconductive materials, between samarium and permanent magnets. There is a particular concern to reassess the various physical properties of these metals and for their application in functional materials. According to the Rare Metal Handbook, 1954, by Hampel, rare metals are defined as having any of the following characteristics: 1) Deposits of ore are scarce; 2) ore content of economic grade or economically exploitable grade is scarce; 3) metallization is difficult; 4) no appropriate applications are found. Elements regarded as rare metals presently number about 50. Important functions manifested by these elements in the form of elements, alloys, and compounds, and in bulk, film, or amorphous form have been reported to number over 200.

Functional rare metal raw materials are actively used in advanced technologies over a wide range and include superconductivity, magnetism, semiconductors, optoelectronics, engineering ceramics, and catalysts. Let us look at some of the recent developments in raw metal materials and also look at future developments.

High Performance Magnets

Intermetallic compounds involving iron, cobalt, and elements of the light rare earth group are noted as raw materials for permanent magnets because of their high crystalline magnetic anisotropy. Following the development of the samarium-cobalt magnet some 10 years ago, a sintered type ($360KJ/m^2$) neodymium magnet was developed in Japan 2 years ago. It attracted the attention of nations around the world because of its strength, the most powerful of all types of magnets at present. General Electric of the United States which had been charging ahead with research on amorphous magnetic alloys, announced the development of a neodymium magnet of the rapidly quenched type a little later. However, this magnet does not compare with the sinter type in performance. Extensive research on the metallic phase and properties of this magnet is to take place. It has recently been proved, however, that its main phase is represented by the tetragonal system of the intermetallic compound $N\alpha_2 \cdot Fe_{14} \cdot B$, with a high magnetic anisotropy in the direction of its C-axis. In terms of its properties as a raw material, poor temperature characteristics attributable to its comparatively low curie temperature, and low resistance to corrosion are yet to be resolved. However, efforts are being made to improve its characteristics by, for example, the addition of cobalt.

The development of a samarium cobalt magnet, meanwhile, has shifted the focus from the 1-5 type to the 2-17 type of a polycomponent system. This differs

entirely from the former in the method of manufacture and in the mechanism of magnetization. It is expected that R&D on this magnet will be quite active by virtue of the incentive afforded by the emergence of the neodymium magnet. In the field of permanent magnets, it is said that the creation of raw materials through the efforts of the metallurgist always leaves behind study of the physical properties, which have yet to be resolved in many cases.

Media for Photoelectromagnetic Recording

Requirements for a high-density recording medium with a capacity for repeated recordings has increased with increasing quantities of information. The photoelectromagnetic recording, which has both recording and playback, is again in the limelight. An amorphous alloy in film made from a heavy rare-earth element and a transition metal is most promising as the medium. The alloy between the two groups of elements is usually an intermetallic compound of specific composition, but rendering the material amorphous has permitted the selection of the optimum composition required for vertical magnetization of the medium in any range. It also eliminated problems of noise or false information signals arising from dispersion of light at the grain boundary. The reading of signals is made by means of the magnetic Kerr effect or the rotation of the plane of polarized light which takes place upon reflection of light on the surface of magnetic objects. The specific properties are being stepped up using three-element alloys and multiple-layer film with the three element alloy Tb-Fe-Co and the multiple layer film Tb-Fe-Gd-Fe-Co affording the best results.

Superconductive Materials

Whereas the critical temperature, Tc, of currently available superconductive wire rods is 16 K, it is desired that a material of high Tc be developed which at least permits the use of liquid hydrogen of bp 20.3 K as coolant because of the projected tight supply of helium in the future. The record highest Tc achieved, 23K for the alloy Nb_3-Ge, has yet to be broken in the past 10 years. The material, however, is not easily processed into wire.

Exploration and creation of materials of high Tc is currently underway using the material design method. After having analyzed past data of Tc over 500 materials, it has been established that combinations of group Va and group III b or IV b, in the periodic table, are most promising as structural constituents and type A15 and type B1 as crystal structures. Furthermore, on the basis of the Mathias empirical rule, i.e., the relationship between Tc and the number of valence electrons per atom, high values of Tc have been predicted for the alloy Nb_3Si and for those of high degree of orderliness, NbC, NbN, MoN, etc. These compounds, however, are nonequilibrium substances and are not amenable to synthesis by ordinary means. No crystals of predicted Tc values have yet been obtained in spite of attempts to create them by such means as sputtering, high pressure synthesis, and shock compression by explosive materials.

Giant Single Crystals of Molybdenum

In spite of excellent mechanical properties exhibited at high temperatures, molybdenum is subject to easy breakage of grain boundary in vicinity of room temperature due to its DBTT (ductility brittleness transition temperature). One of the methods for solving this problem is to eliminate the grain boundary itself. A method has been developed to produce molybdenum made entirely of one single crystal. This is done by applying the phenomenon of extraordinary growth of secondary recrystallized grains which are sometimes observed at the time of metal annealing. The principle of this method involves suppressing normal growth up to the critical temperature and inducing rapid extraordinary growth beyond that temperature. This method, which is also comparatively simple, features addition of some depressant, e.g., Ca or Mg, and heavy processing in order to obtain an appropriate base crystal structure. It has already produced a giant single crystal, 10 x 150 x 150 mm.

The polished surface of a plate of this single crystal has no stepwise unevenness due to the grain boundary, and affords a coefficient of reflection even higher than 99.8 percent. The element molybdenum, though more a structural than a functional material, is expected to play a major functional role with the giant single crystal, serving as reflective plates for high power laser beams.

These are a few examples of recent developments in metallic functional raw materials of the rare metal group. It is expected that exploration of more sophisticated and flexible functions than ever before will be needed in connection with the development of innovative technologies which provide the basis for advanced technologies in the future. It is necessary for the development of raw materials that not only physical properties of the rare metals be used, but also new functions must be developed through exploration of the material's unknown or potential physical properties. Research on subjects of probable growth in a systematic and comprehensive manner is important. It is said that discovery of new functions often results from serendipity, i.e., one often finds, unintentionally, treasures while looking for something else. It seems a key to discovery to obtain highly pure raw materials where systematic and comprehensive research is concerned (see figure).

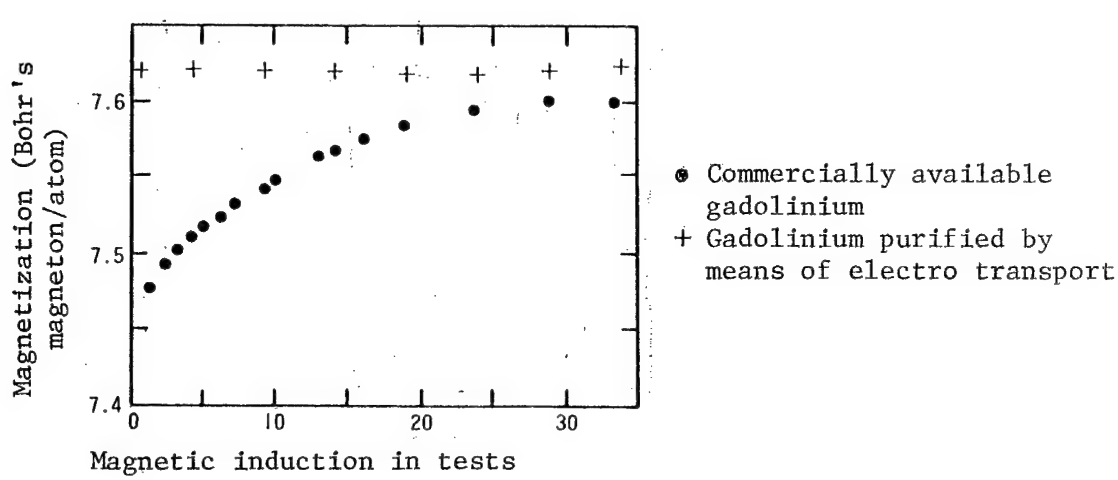


Figure. Gadolinium Magnetization Characteristics at Low Temperatures

It had been regarded as difficult to grow P-type crystals for semiconductors of the II to VI groups, which have good prospects as raw materials for opto-electronics. However, it has recently been suggested that something similar is obtainable by purification of the raw material to a higher degree. If both types become available, the development of visible light lasers and high-efficiency diodes are expected as a great step forward in the application of semiconductors of the II-VI groups. It has also been reported that rare earth group metals samarium and gadolinium have their magnet performances and low temperature magnetization characteristics improved to a remarkable extent by lowering their impure oxygen content.

Hayashi's Superfine Particle Project

Tokyo PUROMETEUSU in Japanese Sep-Oct 85 pp 32-33

[Article by Seiichiro Gashu, technology adviser, Hayashi Superfine Particle Project]

[Text] Superfine particles are fine particles of metals and metal compounds below 0.1 μ in size. The present project is primarily aimed at understanding the specific properties of superfine particles, i.e., low melting points, high-magnetic characteristics, highly activated catalyst characteristics, and also at finding applications as new raw materials.

Before the project was begun, no systematic research had been done on superfine particles from 10Å to 1,000 Å in size. It was expected that specific properties of the superfine particles would open new research in terms of physics and engineering.

Past observations had indicated that superfine metal particles behave differently from other available raw materials at low temperatures and at normal or near normal temperatures. This has lent support to the prediction that the particle will be a useful raw material in future advanced technologies. It had been expected also that research on interaction between superfine particles and biological functions would produce new, useful knowledge because of the magnitude of superfine particles, and because of the magnitude and diversity of reaction energy for each single particle. From this viewpoint, the project was started in October 1981, the first in the Exploratory Research of Advanced Technologies. It has since made a number of remarkable achievements.

Research Results and Future Prospects

(1) Superfine Structure of Superfine Particles

The project team successfully took a picture of aluminum atoms constituting an alumina superfine particle after having analyzed, with a high-resolution electron microscope, superfine particles of oxides, such as alumina and iron oxides, of high purity and of a diameter below several hundred angstroms. Furthermore, the team succeeded in understanding the fusion process of two alumina superfine particles at the level of atoms, and in obtaining new

information on interaction between the surface of the superfine alumina particle and metal clusters where the former absorbs the latter.

This achievement, taking the lead in research, has established an analytical method, using the electron microscope, for the microscopic structure of the superfine particles. This research is expected to make long strides in the coming years.

Application of these particles in the ceramic industry, in the catalytic chemistry industry, and in the semiconductor industry are in the offing.

(2) Discovery of New Physical Phenomenon for Superfine Gold Particles

The project team has successfully created a remarkable method for the direct observation, in terms of time, of the movement of atoms of superfine particles. Its first achievement, reported through continuous observations, by means of VTR's, was the behavior of gold atoms, first in the world.

We have learned that superfine gold particles change their external form just as amoeba does and that gold atoms on the surface also move around.

No other report has ever been made on such behavior of gold at the level of atoms. The question of why such a phenomenon takes place has yet to be understood theoretically (see photograph [omitted]). The discovery of this new phenomenon should contribute in large measure not only to research on basic science but also to applied uses. That is, it should contribute to research on advanced technologies such as the catalyst industry, the raw materials industry, and the semiconductor industry, where an understanding of the behavior of substances at the level of atoms is needed.

(3) Arrangement of Superfine Particles in Lattice Form

Superfine particles usually exist as a mass, arranged irregularly. Where the application of superfine particles is concerned, however, the function of the particle cannot be elicited fully if the mass has irregularly arranged particles. If the arrangement of superfine particles is made regular, one can reasonably hope to bring out a point contact device, for example, which is far better in function than that so far available. It may also be possible to open new fields of application. To be concrete, the project team succeeded in arranging regularly, in lattice pattern, superfine gold particles 200 to 400Å in size on a silicon wafer. This is done by sweeping and irradiating, in the lattice pattern, a fine beam of electrons on the wafer and, subsequently, by vacuum depositing on it gold in thicknesses of 30 to 40Å and heating the metal.

This achievement may possibly allow for elementary devices for microwaves or print-contact elements which are based in contact between superfine particles which excel in comparison with conventional ones. It may also conceivably have applications in superhigh density recording media and in technology for superfine processing. Where academic research is concerned, this system of arrangement of superfine particles should lead to the discovery of new

physical properties of electrons at low temperatures by virtue of the delicate size and periodicity in arrangement of the particle.

(4) Synthesis of Uniformly Mixed Alloys

Because there is no suitable method for uniformly mixing metals of different specific gravities on the earth, experiments have recently been carried out in space. However, the cost and labor involved in one experiment is tremendous. By noting that the difference in specific gravity of metals virtually disappears when the metal is made "superfine," the team successfully prepared an alloy of uniform consistency by mixing superfine particles of different specific gravities in argon gas uniformly. The team then sprayed the mixture, using the differences in pressure, from a nozzle onto a base plate of glass, metal, plastic, etc., at a speed of 30 meters per second. This method permits molding of metals into a thick film or a small mass without applying either heat or pressure and without the addition of a binder of polymers, etc.

This method for synthesis of new raw materials from superfine particles, features control of alloys by varying the spraying condition and uniform blending of the component materials at the level of submicron. It should be a remarkable method for the development of raw materials, e.g., alloys and composite materials, which are not amenable to ordinary synthetic methods.

Once this method is established, one can expect that some of the experiments that use the space shuttle and need vast expenditures will be replaced by those carried out at lower prices on the ground.

(5) Removal of the Photoresist Coating by Means of Superfine Particles of Carbon Dioxide Gas

Carbon dioxide in the liquid state at normal temperatures is subjected to free expansion through a needle valve such that it turns into superfine particles or dry ice and is blown through a nozzle of 1 millimeter internal diameter onto a film of photoresist coating. The film exhibited a sharply bordered area of removal of the material. No contamination due to small photoresist pieces was noted.

This method of removing coatings on the base plate can be carried out in a dry atmosphere and is free of contamination by solutions, e.g., peel off agents, and also free of damage to the surface of the base plate. It therefore is extremely useful as a method for processing semiconductors and for cleaning the walls of vessels of superhigh vacuum. Industries involved are expected to commercialize it and, in the future, to develop it as a processing method for the fine finishing of surfaces.

(6) Coating of the Surface of Superfine Particles by Polymers

Superfine iron particles, which are in chain form under usual conditions, were subjected to cleavage by treatment with supersonic waves and then monomers of various types were added to the particles to allow polymerization.

The resultant superfine particles had a film thickness coating of 100Å to 200Å.

If this coated superfine iron particle can be linked to medicine and induced to migrate to a desired part of the body through magnetic force, it would be a major contribution to medicine. Where fermentation is concerned, one may also expect that an antibody of a useful microorganism could be linked to the surface of the coated superfine particle such that the particular microorganism would be separated from the soil by magnetic force.

These results were presented as representative of the research in which the project team is engaged. For the remaining 1 year, until September 1986 when the contract expires, the team will press ahead with research on superfine particles in various sectors.

R&D in Space

Tokyo PUROMETEUSU in Japanese Sep-Oct 85 pp 34-35

[Article by Nobiyuki Tsujiuchi, deputy director, Social Systems Division, Mitsubishi General Research Institute]

[Text] Development of Plan for Utilization of Space Environments

The early U.S. space program was aimed at creating a rocket propulsion system in space and appropriate welding technologies. Research was pushed ahead with the use of a fall tower which allows nongravity of approximately 5 to 10 seconds. However, the experiments using the fall tower and airplanes which afford only short periods of weightlessness were superseded by experiments on microgravity of long durations in the Apollo project by the middle of the 1960's. This experiment on microgravity, in turn, was turned over to the Skylab project and then to the Apollo-Soyuz project, the latter carried out jointly by the United States and the Soviet Union. Finally, research on microgravity has recently involved use of the space shuttle.

The space shuttle is unprecedented in scientific research on microgravity and related applications, and permits experiments larger in scale and more sophisticated than any undertaken before. The realization of the heavy payload of the shuttle and its capacity for repeated flights have permitted NASA to widen the range of purely scientific and commercially intended research in space in great measure. In the 1980's and beyond, research on microgravity and, in particular, experiments on raw materials will be the major subject of research in the space development program. In Japan, the FMPT project, the first raw materials experiment, has been set up which is slated to be implemented in 1988 in the space shuttle. The project, as shown in the table, involves experiments which are associated with various types of raw materials such as semiconductors, metals, alloys, composite materials, glass, and ceramics. This indicates the high hope Japan has for development of new raw materials using space.

Table. Effective Utilization of Space and New Raw Materials Mapped Out in FMPT (First Materials Program for Tests)

Sector of raw materials / Advantages afforded by space	Large-size crystals and uniform consistency	Perfect crystals	Homogeneous consistency and uniform shape	High purity
Semiconductors	•Lead-tin-tellurium: zone melting method (large area infrared image sensor) •Indium-antimonium compound semiconductor (superhigh speed logical element) •Crystals of organic metals (new type of raw materials with electronic functions) •Indium-GaAs compound semiconductor (superhigh speed electronic element, raw materials for optoelectronics)	•Lead-tin-tellurium: unidirectional solidification (infrared sensor of high performance) •Silicon globule (development of technologies for the manufacture of semiconductors	•Silicon-arsenic-tellurium amorphous semiconductor (solar cell of high efficiency)	
Metals and alloys	•Aluminum-lead-bismuth alloy (new superconductive alloy) •Aluminum-indium alloy (superconductive alloy) •Mechanism of the formation of deoxygenated products in steel mass (improvement in steel making technology)		•Research on the mechanism of liquid phase sintering: tungsten (solid phase)-nickel (liquid phase) •Research on solidification of eutectic type alloys: aluminum-copper; aluminum-nickel •Mutual diffusion of two fused metals: gold-silver, gold-aluminum •Research on the mechanism of solidification of metals in the gas state: magnesium, chromium, iron, zinc, etc.	
Composite materials			•Nickel-based alloys with ceramic particles dispersed (heat-resistant alloy) •Composite material of carbon fiber and aluminum alloy (fiber-reinforced metal of high strength and supersmall weight)	
Glass and ceramics	•Samarskite (electrode material for photochemical reaction)		•Behavior of glass at high temperature (glass of superhigh resistance to heat, materials resistant to heat and shock)	•Optical material for nonvisible regions (optical material for laser)
Fluid physics	•Research on the Marangoni convection (development of technologies for processing materials for space science)	•Behavior of bubbles, development of theories for crystal defects		•Floating of drops of liquids on second waves (development of technologies for float processing)

Processing of Raw Materials in Space

Raw materials processing, as exemplified by the production of single silicon crystals from ore, is a technology for making various value-added products, e.g., crystals, chemicals, metals, and ceramics, from common low-priced raw materials.

The most important reason for conducting raw materials experiments in space is to make use of its weightless environment. On the earth, substances separate from each other according to their difference in temperature and density and because of their gravity, producing changes in shape owing to its weight. In weightless raw material processing, on the other hand, growth of semiconductor single crystals, far more homogeneous and much nearer perfection than on the earth, is conceivable. This is also true for mixing and solidification, through containerless processing, of metals and ceramics which are of a shape and purity not to be attained on the earth. Outer space permits manufacture of high-value raw materials both in scientific and commercial terms using weightlessness.

(1) Electronic Raw Materials

Improvement of the technology for manufacturing semiconductor crystals has played an extremely important role in the development of computers, lasers, and a variety of sensors. Crystalline structures and purity are vital factors in this technology development such that even 1 ppb impurities (one-billionth) can sometimes render a crystal defective, just as structural defects of even the atomic level can produce fatal effects on some occasions. On the earth, these problems can be surmounted only partially by complex and uneconomical means. However, in weightlessness, large, near perfect single crystals can be grown with comparative ease because of the lack of natural convection that produces uneven growth surfaces and distorted growth zones.

(2) Metals

Weightlessness is important in directional solidification, a major technology for raw materials processing. By imparting directional features to metal at the time of its solidification, some characteristics of the metal can be strengthened. A unidirectionally solidified metal should be an essential raw material for such products as turbine engines, where heavy stress is applied in one single direction and where a large strain is produced in that direction.

Another important promising process in space is rapid quenching. In this process, a metal is solidified at such a rapid rate that its constituent atoms cannot settle themselves in their unique structural arrangement. Consequently, a random structure is produced like that of glass with unusual properties. Such research of technologies in space is expected to advance metal casting technologies developed on the earth. The manufacture of new types of superconductive alloys, for which assessment of special properties is not possible on earth because differences in specific gravity of component metals prevent the metals from mixing properly, is also one research theme uniquely adapted to space.

(3) Glass and Ceramics

Where ceramics are used in turbine blades, jet engines, etc., which are subjected to high temperatures and heavy stress, a matter of concern is the destruction of the material. One method for dealing with this problem involves improvement of the performance of the ceramic by the addition of some specific metal to the material. This controls its microscopic structure. In such a case, weightlessness again provides an important means of research. Nongravity in space permits one to prepare a microscopic structure which is unavailable on earth because of the absence in space of up and down movement of the component materials based on the differences of specific gravities, among other things. That is, it provides important knowledge for the development of high-function raw materials.

Another important field of application for processing raw materials in space is that of development of optical fibers for use in optical communications. The manufacture of optical fiber with a low attenuation coefficient for light, which is required for sending signals over long distances, should be made possible by containerless treatment in space. This permits fusion and solidification of crystals under conditions that preclude any contamination by impurities derived from a container and makes it possible to produce highly pure glass with high transmittance.

Future Prospects

According to NASA, microgravity science and appropriate application programs are aimed at the application of the weightless environment in space with a view to obtaining a deeper understanding of its physical implications and also to develop further technologies for the manufacture of raw materials. In this series of projects NASA has mapped out a plan starting with experiments using fall tubes and fall towers on the ground, advanced to airplanes and sounding rockets in semiorbits, and is presently using the space shuttle in orbit, to be followed by a space station, also in orbit.

Utilization of space environments must include efforts to develop applications of that environment in industrial technology, made simultaneously with efforts to put in order the yet unknown physical phenomena under weightless conditions as part of science. In this sense, progress in the science of weightlessness may require a system of research in which the government, industry, and academic circles have to cooperate more intimately than ever before. We may see in the future new S&T prospering in space.

21st Century Opened

Tokyo PUROMETEUSU in Japanese Sep-Oct 85 pp 36-37

[Article by Ei Yamada, chief researcher, Office for Research of Polymer Chemistry, Institute of Physical and Chemical Research]

[Text] Proposal for Development of Hybrid Raw Materials

Raw materials appear to be grouped into three types, organic, inorganic, and metals, both for science and for the raw materials industries which use them. Requirements for raw materials of industry, however, have for 20 or 30 years been centered on so-called "composite" materials, where the three major raw materials are combined to supplement each other's physical properties.

If we consider the development of new raw materials from the standpoint of creative work, we need to reevaluate the materials at the level of atoms and molecules which made up the structure. If we allow for progress in raw materials, at this juncture, we must note the emergence, as a historical necessity, of hybrid materials. These result from coupling or composition of the three major parent materials. Hybrid materials are in the interdisciplinary region of the three major materials.

Since the oil crises, emphasis on materials and stocks has been put more on their durability and their fine chemical aspects than on the quantity of consumption. Furthermore, in parallel with the prevailing achievements of life science, a trend for imitating functions of life by imparting them in materials and stocks has been gathering force. Just as synthetic fibers were produced by imitating silk, so the era of materials science imitates the functions of life.

Against this background, the author suggested developmental research on "frontier" raw materials in 1981. A proposal made in 1982 at a meeting of the Committee for Research and Investigation of Hybrid Materials by Yamada, Suzumebe, and Miyata materialized in 1983 as the "Report on the Survey for Creation of New Materials Based on Hybridization of Raw Materials" (chairman Choichi Nizoki) of the Bureau of Research and Coordination, STA. Also, the "Research on Basic Technologies for the Creation of New Raw Materials Based on Technology of Designing Hybridized Structures" was begun in FY 1984 with a budget coming from funds for the promotion and coordination of S&T with cooperation from research organs of other ministries and agencies of the government.

Concept of Hybrid Materials

The term "hybrid material" suggested by the author derives from the term hybrid orbital found in the molecular orbital theory of chemistry. If a material of an interdisciplinary region is formed from different materials of organic, inorganic, and metallic types, there must be produced, among atoms of these different types of raw materials, an intermolecular reciprocal

force suggesting the formation of hybrid orbitals. Many findings indicate the possibility of hybrid materials. For example, compounds such as organic complex salts and organic metals, intermetallic compounds, and inorganic semiconductors may be taken as having crossed the boundary for the three categories of raw materials and entered into the interdisciplinary region.

The structure of the center of activation of a catalyst, meanwhile, is one that is not amenable to the conventional theory of chemical bonding. It provides a vast amount of information on the formation of structures among different types of atom groups. Hybrid materials are aimed largely at three targets: structural, functional, and biological. Hybrid materials for structural purposes are the ultimate form of composite materials. They are produced by the addition of intermolecular reciprocal forces, etc., in addition to existing simple chemical bonding such as covalent and metallic ionic, to the design parameters in the design of raw materials, which are presently referred to as microcomposite, molecular composite, and super composite materials. This material can be obtained by reproducing R&D on hybrid materials of functional purposes. The biological or live hybrid material is one that adapts itself to the environment of the living body and carries out some of its functions.

Research on biological hybrid materials has been suggested by young researchers in the author's group of research and investigation. It represents the most novel and creative of the research concepts for biological and medical raw materials in the world. Since prospects for Japan to lead the world in the development of raw materials are good, young researchers may contribute substantially to Japan's future if they are allowed to do this research.

Methods of Manufacture of Hybrid Materials

Functional hybrid materials involved in this research are largely in the solid state. The author's guidelines for the design of solid state functional hybrid materials as synthetic products include the following: 1) the structure must have abnormal distances between atoms and molecules; 2) microscopic groups of atoms and molecules must have some portions where theoretical chemical bonding relations are lacking; 3) interatomic and intermolecular reciprocal forces work between the different types of materials; 4) phases of materials of different types confront one another within a distance in which intermolecular reciprocal forces are working; 5) an anisotropic field exists in the space between structures and arrangements. These abnormal structures and arrangements need to be brought out positively--by what one may call the control of dimensional structure, e.g., superfine particles for zero dimensions, extraordinary orientation and anisotropy for one dimension, superthin film for two dimensions, and lamination for three dimensions.

New functional materials manifest themselves either as a new compound or as a new state of aggregated atoms and molecules. Hence, the conditions given above suggest the need for new technologies to produce raw materials. Though a host of methods, physical, chemical, and mechanical, are available as technologies for producing raw materials, a new method has to be applied if different types of materials are to be hybridized to produce new materials. This implies that ordinary technologies for producing raw materials, which produce an agglomerate

of atoms and molecules in accordance with their nature, turn out merely structures involving phase separation out of a mixture of materials of different types.

Extended Effects of Hybrid Materials

It is predicted that a long-term industrial cycle extending to the 21st century largely involves a social upheaval in the information and communications sector. New energy, aerospace science, and life sciences are also areas where new raw materials, as the driving force, can make a major industrial impact around the world. (See "International Technology Strategy" by Uchida, published by Yuhikaku Corp.)

With its consumer materials industry being usurped by newly industrialized nations, the industrially advanced nations must base their industry more on "fine" technology than on mass production, for the coexistence of the nations of the world. Japan, lacking in natural resources, in particular, has to smoothly convert its industrial structure on the basis of raw materials technology if it is to find a means of sustaining employment in the future. At this juncture, raw materials for the information and communications industry are expected to be a driving force for creating full employment.

It is evident from the above why the development of hybrid materials is aimed at primarily functional applications. Furthermore, structural hybrid materials are expected to lend support to the aerospace industry and life hybrid materials to the life sciences industry.

The present target in connection with functional hybrid materials is the development of transducers and sensors of new functions. This is illustrated in the diagram below in the form of a tree and classified by dimensions of the structure of the raw material. It is probable that hybridization of raw materials by means of the fusion of entirely new materials of different material types can lead to the discovery of unexpected physical properties and functions. The new science of materials must be established by the fusion of physics and chemistry, a science which also includes both "superphysical" phenomena such as superconductivity, superionic conduction, superintegrated circuit elements and supermemories, and understanding the mystical mechanisms inherent in life. The author is convinced that hybrid materials lend themselves to developing industries associated with sophisticated information networks from a short-term viewpoint, and contribute to the development of the science of new materials by affording interesting subjects of research from a long-term viewpoint. The author also hopes that research on hybrid materials will provide an opportunity for creative research to young Japanese researchers with the support of the people, in general.

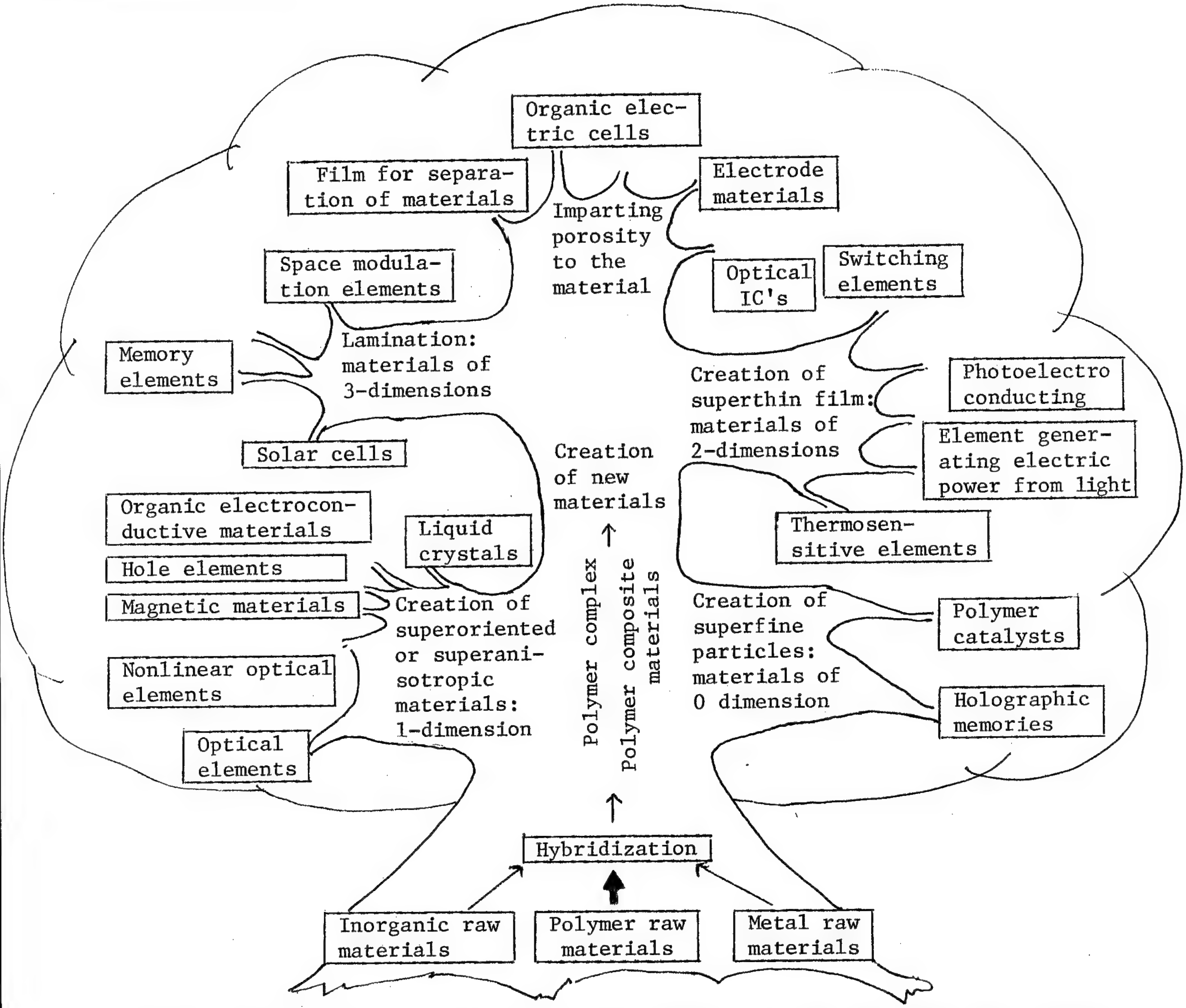


Figure. Technologies for Creation and Development of Raw Materials That Permit Conversion of Energy and Information of Means of "Specialty Materialization"

Metals With New Functions

Tokyo PUROMETEUSU in Japanese Sep-Oct 85 pp 38-41

[Article by Masahiko Suzuki, deputy director, Technology Planning Division, New Raw Material Enterprise Development Department, Shinnittetsu Corp.]

[Text] Interest in new raw materials is extraordinarly high and is growing in recent years among researchers. R&D has been stepped up in a variety of industrial sectors and new products with diverse properties and functions have been introduced one after another.

In the field of metal raw materials, where characteristics such as strength, toughness, ductility, malleability, and electric conductivity were largely made use of in the past, functional metal materials with properties and functions never seen before have been developed in large numbers. Examples include amorphous metals, hydrogen absorption alloys, shape memory alloys, and superconductive materials, among others. The author describes below hydrogen absorption alloys with iron and shape memory alloys.

Hydrogen Absorption Alloys

The manufacture of hydrogen absorption alloys dates back to the development of the alloy La-Ni by Phillips Corp. of Holland in the latter half of the 1960's. A large number of alloys have since been developed. Certain types of metals, in a hydrogen atmosphere, react with hydrogen at appropriate temperatures and pressures to produce a metal hydride. This is a reversible reaction with the reaction formula $M + H_2 \rightleftarrows MH_2 + \Delta Q$. The reaction proceeds to the right and the metal absorbs hydrogen either by applying pressure or by cooling (exothermic reaction). Conversely, the reaction proceeds to the left and the metal relinquishes hydrogen endothermically upon application of heat or reduction of pressure. Alloys that absorb and relinquish hydrogen on the basis of this reaction are referred to as hydrogen absorption alloys. The metal hydride thus produced by the reaction with hydrogen is very dense, around 1,000 times that of gaseous hydrogen under normal conditions of 5.4×10^{19} atoms per cubic centimeter, and is of an order equivalent to that of liquid hydrogen. Representative alloys used for the formation of hydrides are the La-Ni series, Mg-Ni series, and Fe-Ti series, each having advantages and disadvantages in their properties.

The alloy La-Ni, for example, reacts quickly, has no difficulty in the early phase of hydridization, has a flat plateau at around room temperatures under several atmospheric pressures, and has a hydrogen density for its hydride $LaNi_5H_6$ of 7.6×10^{22} atoms per cubic centimeters. Nevertheless, it has a low hydrogen content by weight of 1.4 percent and is very expensive because of the use of La.

The alloy Mg-Ni, in turn, is lighter and has a hydrogen content by weight of 3.6 percent for its hydride Mg_2NiH_4. However, it has disadvantages in that it reacts more slowly and that the temperature required for the release of hydrogen is as high as over 250°C.

The alloy Fe-Ti, finally, has a hydrogen density of 5.7×10^{22} atoms per cubic centimeter for the hydride $FeTiH_2$, has a comparatively high hydrogen content of 1.8 percent by weight, relinquishes hydrogen at room temperatures under several atmospheres, and is inexpensive. It, therefore, is a very promising alloy, though it also has disadvantages of being heavy and having difficulties in activation of the alloy, i.e., in making the alloy ready to react with hydrogen in the initial phase of the reaction.

Many attempts have been made to improve this activation of the reaction, and it has been demonstrated that replacing part of Fe by Nb, Mn, Ti, etc., improves the activation properties of the alloy. The replacement of Fe by Nb, however, results in an expensive alloy, while using Mn or Ti produces undesirable plateau characteristics, i.e., the equilibrium pressure for the liberation of hydrogen from the hydride varies and leads to reduction of the quantity of liberated hydrogen, thereby reducing the value of the alloy.

Researchers have pressed ahead with research for an alloy that has an improved activation properties but retains the advantages of the Fe-Ti alloy. Their efforts resulted in the Fe-Ti-S series and Fe-Ti-Mm series of alloys.

(1) Fe-Ti-S Hydrogen Absorption Alloys

The alloy Fe-Ti generally attains a maximum value of effective hydrogen absorbed and released, as represented by the atomic ratio H/M, of 0.5 at an atomic Ti-to-Fe ratio of the alloy of 1.0, and also exhibits good plateau characteristics. It has yet to have its temperature raised to over 400°C for activation. At a relevant Ti to Fe ratio of over 1.0, on the other hand, the activation temperature drops, but the plateau characteristics become worse.

The Fe-Ti-S alloy, where S is added to the Fe-Ti alloy, has proved to have both an improved H/M ratio and better plateau characteristics. Whereas the activation of the Fe-Ti alloy required a temperature of 450°C and a period of over 150 hours, that of the more recently developed Fe-Ti-S alloy needs merely a temperature of no more than 100°C and an activation period of less than 20 hours, with an H/M ratio retained at a high value, providing the composition of the constituent elements is properly selected.

(2) Fe-Ti-Mn Series of Alloys

To further improve the activation characteristics of the Fe-Ti-S alloy, an alloy with a mesh metal, Mm, added to the Fe-Ti alloy has been developed. By providing an atomic ratio of Mm to Fe of over 0.05 and by selecting an appropriate Ti/Fe ratio, the activation temperature was brought down to room temperature and the activation period to less than several hours. The mesh metal contains such metals as La, Ce, and Nd and, of these, Ce activates the metal.

An alloy with further advanced activation and plateau characteristics, the Fe-Ti-Mm-S alloy, has also been developed from the Fe-Ti-Mm alloy by adding appropriate amounts of S to the latter alloy on the basis of Ti and Mm.

These alloys are excellent in their durability since it has been proved by durability tests that they suffer no deterioration of performance after repetition of the reaction 10,000 times.

Figure 1 shows hydrogen pressure versus the atomic composition of a hydride for different temperatures and for an alloy of Fe-Ti series. Characteristics of the alloys of Fe-Ti series in comparison with the representative La-Ni alloy are in Table 1.

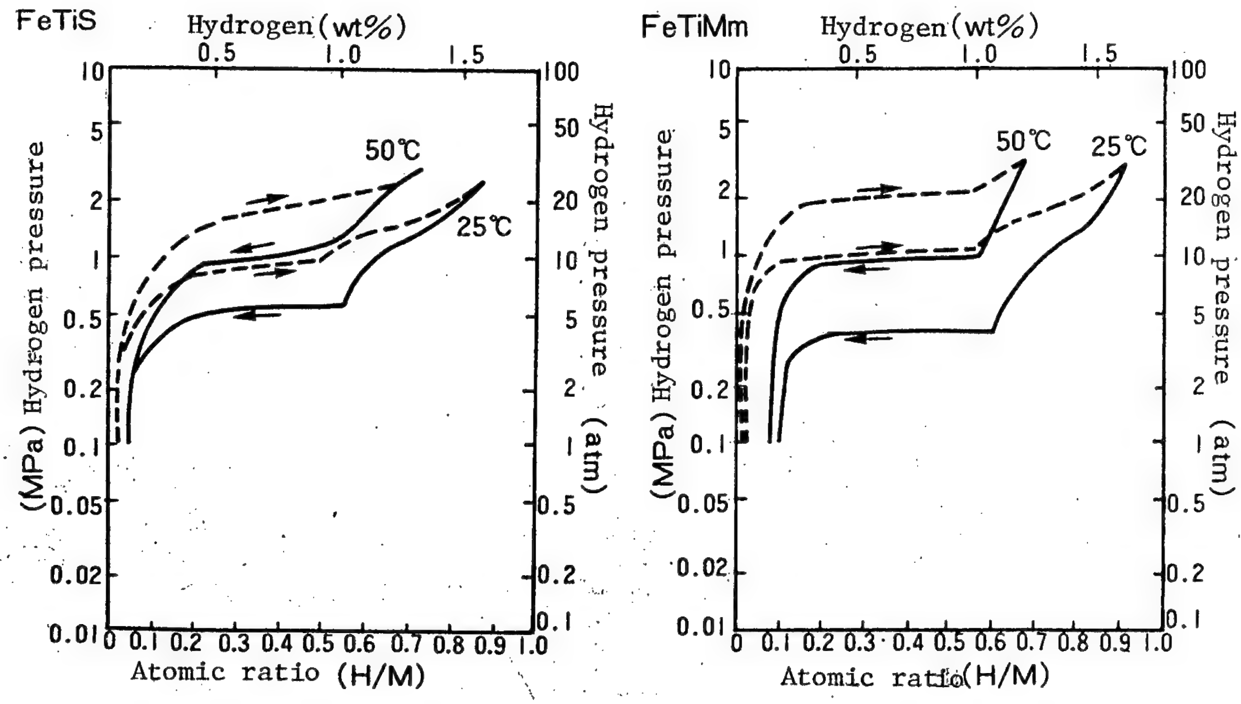


Figure 1. P-C-T Curves for Hydrogen Absorption Alloys of Fe-Ti Series

Table 1. Comparison of Major Characteristics of Hydrogen Absorption Alloys

Alloy series	Fe-Ti-S	Fe-Ti-Mm	Fe-Ti-Mm-S	La-Ni
Hydrogen content (wt %)	1.8	1.8	1.8	1.4
Pressure for the release of H_2 (atm)	4 5	4	4	2.5
Temperature for release of H_2 (°C)	25	25	25	30
Heat of formation (kcal/mol-H_2)	5.2	6.7	6.7	7.3
Amount of H_2 absorbed (liters per kg of alloy)	200	200	200	155

Shape Memory Alloys

When a metal has been subjected to plastic changes in shape by the application of external stress, it generally does not change its shape when the stress is removed just as it does not with changes of temperature.

Some alloys, however, exhibit special characteristics in that after having undergone a plastic change, they regain their original shape upon application of heat. This phenomenon is referred to as the shape memory effect. Alloys exhibiting this phenomenon are shape memory alloys. These alloys are in the limelight as new functional metal raw materials. The shape memory effect for metals was first discovered in the Au-Cd and In-Tl alloys in the early 1950's, and since the Naval Ordnance Laboratory discovered a pronounced shape memory effect in the alloy Ni-Ti in 1963, active research on this type of alloy has continued. The alloy Ni-Ti is referred to as Nitinol by combining the names of the metal constituents with the capital letter of the name of the laboratory, and is the representative of this type of alloy.

In the 1970's, research became wideranging, the mechanism of the phenomenon became much better understood, and a large number of alloys of this type have been discovered. Practical application of this type of alloy is found, however, almost exclusively with the alloy Ni-Ti, except for the alloy Cu-Zn-Al, which accounts for a minor portion of the total.

The shape memory effect is based on the martensite transformation and its reverse transformation. For Ni-Ti and related alloys the reaction involved is a reciprocal transformation between a parent phase of regular structure and a martensite phase of the thermoelastic type, where martensite crystals, once developed, grow at a rate proportional to that of cooling. Alloys of a shape to be memorized are subjected to heat treatment, i.e., a shape memory treatment such that the alloy "memorizes" the shape. The alloy is then subjected, by cooling, to a phase transformation into martensite, which retains its original shape. The resultant material has many twines and is readily amenable to shape changes by applying external stress. The shape change thus produced, as distinct from the plastic or slipping deformation found in ordinary metallic materials, does not involve a change in the bonding of atoms. This changed shape, finally, is returned to its original by applying heat. The alloy undergoes reverse transformation into the austenite phase stable at high temperatures since the relevant movement of atoms is limited in a specific direction.

The shape memory effect is a phenomenon where an alloy, which has the martensite phase at low temperatures, is subjected by application of some force, to a shape change at a temperature below the maximum (Md) under which the martensite phase prevails. Subsequently, it is again subjected to a shape change to bring back its original shape along with its original phase by heating it above the final temperature (Af) of reverse transformation. This phenomenon is referred to as an alloy memorizing its original shape.

(1) New Shape Memory Alloys Based on Iron

The martensite transformation, which is closely associated with the shape memory effect, has long been known in steel. However, the martensite transformation in steel, except for regular Fe-Pt alloys, is exclusively of the nonthermoelastic type, i.e., individual martensite crystals develop and grow at a rapid rate on the order of magnitude of 10^{-7} second and thereafter grow no more, either with drops in temperature or with the passage of time. This transformation, hence, exhibits no shape memory effect.

It is known, however, that iron-based alloys, such as the Fe-Ni series, exhibit the shape memory effect by virtue of a transformation between γ phase (face-centered cubic crystals) and the ε phase (close-packed hexagonal crystals). This shape memory effect occurs only partially and is far from perfect because it involves α' martensite (body-centered tetragonal crystals) besides the $\gamma \rightarrow \varepsilon$ transformation, and produces slip deformations in addition to the "normal" transformation.

Researchers have focused their attention on the Fe-Mn alloy, which is free from the α'-phase formation. It has been proved that this alloy does not give a satisfactory shape memory effect when the proportion of the constituent metal Mn exceeds 25 percent. Thus, the γ-phase is stabilized and the γ-ε transformation is prevented. Addition of silicon, which was found to enhance the γ-phase formation, to the alloy Fe-Mn at this juncture, leads to the creation of a new iron-based shape memory alloy with an enhanced effect. Fe-Mn-Si alloys afford fine shape memory effects providing the composition of the component metals is selected appropriately. One problem that lowers the effect, which results when the slip deformation of the γ-phase takes place along with the $\gamma \rightarrow \varepsilon$ transformation, and from transformed ε-phase of a kind not reversible to the original phase, is eliminated by addition of other elements which promote the $\gamma \rightarrow \varepsilon$ transformation, and by subjecting the alloy to appropriate heat-treatment. A full-fledged shape memory alloy is thus provided.

This is the new shape memory alloy of the Fe-Mn-S series, where the shape memory effect is induced by external stress on the martensite phase of transformation. This new iron-based alloy has the disadvantage that it has a high Af temperature--the temperature at which the martensite phase is eliminated and the original shape restored through the reverse transformation caused by applying heat. This is in comparison with the alloy Cu-Zn-Al, and others, with a shape memory effect which is unidirectional. This alloy is favored over the others, in that, made largely of iron, it is available as a structural material and, in terms of economy, it is far less expensive than the other shape memory alloys because existing processes for steel manufacture are available for its manufacture with no changes required.

Table 2 compares major characteristics of the Fe-Mn-Si series of shape memory alloys with those of the other representative series.

Table 2. Comparison of Major Characteristics of Shape Memory Alloys

Alloy series	Fe-Mn-Si	Ni-Ti	Cu-Zn-Aℓ
Density (g/cm^3)	7.0 - 7.8	6.4 - 6.5	7.7 - 8.0
Melting point (°C)	1,400-1,450	1,240-1,310	to 1,230
Tensile strength (kgf/mm^2)	70 - 100	70 - 110	50 - 60
Yield point (kgf/mm^2)	30-50 (A phase)	(10-60 (A phase)	8 - 14
Elongation (percent)	12 - 30	20 - 60	6 - 9
Point of transformation (°C)	Af: to 150	Af: 10 - 100	Af: -100 - 100
Shape memory function	Unidirectional	Unidirectional	Two direction

Forum on Raw Materials

Tokyo PUROMETEUSU in Japanese Sep-Oct 85 pp 42-56

[Forum with Yoshiro Miki, member of the National Institute for Research in Inorganic Materials, Seita Yoshida, director of the Institute for Physical and Chemical Research, Noboru Ichinose, professor at Waseda University, Masuo Aizawa, professor of Tsukuba University, Shizuo Asanabe, staff, NEC Corp.]

[Text] Miki: Many nations have recently begun R&D on raw materials in earnest. In Japan, the Council of Science and Technology submitted to the Prime Minister the so-called 11th report, which gave guidelines for the comprehensive development of S&T providing for the 21st century. The council also pointed out requirements for advancing R&D on the S&T of raw materials as a major cornerstone of advanced and basic technological R&D. Let us today, therefore, discuss movements associated with broad raw materials development.

We shall first discuss the historical sequence up to the present time of raw materials development in terms of the special sector of each, including new terms recently used such as new raw materials.

Yoshida: The term raw material has recently taken on a very broad meaning, whether for life or for nonlife. Research on raw materials which has been continuing from prehistoric times has recently, in particular, come into the spotlight because means of understanding the structure and function of various materials have been increased to such a high degree that the manipulation and composition of raw materials in infinitesimal amounts is now possible. This is a great force in pushing scientific research to convert materials into raw materials. The creation of materials of new characteristics and performance by merely extrapolating existing ones may become possible in the coming 15 years, as predicted by some.

Another reason is that, as also referred to in the 11th report, increasing importance is attached to problems associated with information, life, etc., that is, to problems directly associated with the daily life of man. Raw materials, after all, provide the basis to the solution of these problems.

As for metallic raw materials, which will undergo innovations in shape and function in the coming years, there is no doubt that these will find applications in many sectors and in large quantities as in the past.

Life materials, in turn, comprise two trends in their application, as is well known. One is applications of the very functions of life, using life as a raw material. The other is creation of raw materials artificially by simulating functions of life. These two trends are observed also in the application of metals. After starting with the study of the natural behavior of metals--or with the study of the metal material--the application has developed into a kind of artificial raw material including so-called new raw materials. This is a process in which the natural phenomena of metals are precisely simulated.

In the present world of practical industrial raw materials, individual particles and their agglomerates are controlled ingeniously in a wide range, from the magnitude of the submicron to that of very many meters, with a view to gaining what is called intended functions and characteristics. Such precision material designing, or raw material designing, has been completed and is available such that huge installations of steel mills, for example, can precisely control operations on the order of magnitude of the submicron. Many questions, however, remain completely unresolved. One example is formulas and coefficients, which quantitatively represent changes in functions and characteristics as the material undergoes changes from an individual particle of the order of magnitude of the micron to some enormous agglomeration. Computer-aided material designing, a major research problem confronting us for the future, requires an equation of state which correlates related states. It is very basic and important research to devise and formulate equations of state and related coefficients which can determine such functions and states of materials as these changes, from the order of magnitude of atoms and molecules to that of agglomerates, i.e., fine particles and, further, to a shaped object or a solid. It is a gross mistake to say that the time for research on metals is gone, or that research on structural materials has no future. There are many problems for which the metallurgist and the mechanist need to find solutions.

Miki: Would you discuss the relevant problems with ceramics, Professor Ichinose?

Ichinose: From ancient times, ceramics have been produced by molding clay and mud into a shaped body and by baking this for practical applications. Ceramics have recently been spotlighted because of their extremely high functions, and have come gradually to adapt themselves to life.

Ceramics are largely of two types. One has electronic functions, and the other structural functions. The latter type, rather, has recently been in the spotlight in connection with applications in engines, etc.

I have engaged myself in the study of ceramics of the electronic function type for around 26 years. This type is very wideranging and comprises such functions as semiconductors, dielectrics, piezoelectric and magnetic units, with many applications in related sectors.

The ceramics industry has certainly been flourishing and booming, as demonstrated by the Fine Ceramics Fair held annually in February or March in Nagoya City. Here, a surprising 20,000-30,000 people gather to see the exhibition. It is true, meanwhile, that the nations of the world, and particularly the United States, are focusing attention on the ceramics industry in Japan in recent years. About 2 years ago, a group of people came from the United States to Japan to inspect the ceramics industry, and then published a report. Under such circumstances, I hope ceramics will find applications in diverse sectors of life in the future, as they have in the past, and it will not be long before engines using new ceramics show up on the market.

Miki: How about organic polymers, Professor Aizawa? I have recently read many news topics on biological materials.

Aizawa: I am engaged in the study of organic materials and "biorelated" materials which are based, among other things, on chemistry. Chemistry, in turn, always involves the conversion of materials. At this juncture, we interpret the term "material" somewhat differently in the shade of meaning from the term "raw material," though they have similar meanings generally. The term "material" represents a molecular structure exclusively, whereas the term "raw material" places emphasis more on the functions of the entire material. We, thus, have the phrase "From Material to Raw Material."

The chemistry of the past was largely aimed at the manufacture of materials, as it lent itself to the production of medicines and other articles. Since the oil crises, however, petroleum chemistry has particularly declined, and now the term "restoration of chemistry" has emerged. This involves the idea that the real objective of chemistry is to manufacture raw materials with the hope that chemistry can provide man much in the future. The term involves the idea that the chemical researcher should do more for the development of raw materials used in electronics.

There was no difficulty, for example, in producing silicon from ore. However, a major advance had to be made in technology in order to turn the material thus produced into one available for semiconductors using innumerable processes. What was involved was the methodology for purification, I suppose. Many of the raw materials currently used in electronics are the ones which chemistry, at that time, balked at using in research. Almost all of the raw materials used in semiconductors are also the ones which the chemist then was reluctant to use in research.

Such being the case, turning a material into a raw material was successful where requirements were urgent. Allowing for the circumstances given above, the chemist is presently questioning himself again on what role he should play in a chemistry which comprises primarily organic raw materials, polymer materials

and biological materials. The chemist also wonders about streamlining the "front" of research in raw materials on the basis of a rerecognition that raw materials are the very ones to which he is assigned.

Coupled with this point of view is the high ambition or rather vision, talked of by some chemists, that organic materials may provide functions which have hardly been attained, from inorganics such as metals and ceramics. Attempts to manufacture electroconductive materials from organic materials are one example. Another is to produce materials displaying electronic functions at the molecular level. The latter attempt has step-by-step led to the control of functions of materials at the molecular level through control of the arrangement of molecules, as seen in organic polymer raw materials, which adds to conventional control of large aggregate raw materials. Such a technology is being developed, along with manufacture of materials. A material not obtained by this molecular technology, that is, one not amenable to existing synthetic technology, usually has to find its source in living things. This is what we call "biological materials," which so far have found applications in diverse ways. Biomaterials were long unable to gain the entity of a raw material for the reason, among others, that the molecule in living things deteriorates promptly when extracted outside the body. Around 1970, however, technologies were established for stabilizing, to a considerable extent, the biomaterial by combining it with the surface of a solid matrix. This triggered the present trend of regarding biomaterials as available as raw materials.

Miki: Regardless of the groups of metals, ceramics, and organic materials, semiconductor-electronic materials, etc., have currently been in the spotlight to the maximum extent because of their functions, I suppose.

Asanabe: One sees use of the term "new raw material" becoming prevalent among the people these days. For my part, I feel keenly, however, the advent of a third stage for semiconductor materials following their first and second major ones in the past. The first period covered the years up until about 1955, where question of what elements or what combinations of elements could make a semiconductor were investigated almost completely. The second period has seen the technology for precision processing prevailing, where efforts have been made to step up the purity of elements or to add some impure element for the sake of industrial use of the product.

In this respect, silicon and germanium have nearly attained perfection. Research is presently focused on either GaAs, and a view to obtain raw materials of faster functions, or on eutectics, comprising three or four elements, in order to produce a raw material which emits light efficiently enough to permit a communications system of large capacity. The degree of perfection of compound semiconductors such as these, compared with that of silicon, may be 50 to 100, respectively. Along with this research, one can see very recently a technology for laminating films in multiple layers. The principle involved here is that, upon rendering a film thinner and thinner, properties of the film themselves undergo changes. For example, when a few or several layers of atoms of a certain element and those of another element are placed one upon another in alternating fashion, properties different from those of either element begin to emerge--properties of the so-called superlattice.

One may anticipate, in its extreme limit, creation of a new material not yet listed on the periodic table. We are seeing the advent of the third period of semiconductors or an era of new raw materials, including the multiple layer film and superlattice, I presume.

Miki: What do you think then is the present level of technology in Japan relative to the nations of the world, Mr Aizawa? It seems that Japan lags behind others in basic research on organic and polymer chemistries, though it leads the world in some sectors of research by virtue of its efforts.

Aizawa: I don't think that Japan's technology level is so pessimistically low. It is true that Japan has not yet frequently had such technological successes as making abreakthrough where organic and polymerchemistries are concerned. Nevertheless, where electroconductive polymers, for example, are concerned, technologies for makng films of polyacethylene were brought out in Japan and, research here has been gathering force very rapidly. The question is how many such breakthroughs can be produced and how far these can be extended. Where biotechnology is concerned, Japan is in general at a very high technology level, I suppose. There is no denying Japan's failure to bring out the concept and technology of attaching biological materials to solid matrix. However, Japan has displayed its power in expanding rapidly that technology which originated in foreign countries.

Miki: It is often said that Japan should engage itself more in basic and advanced research and thus contribute to the world, isn't it?

Aizawa: It may be true in some aspects, I suppose.

Miki: How about metals and ceramics, Professor Ichinose and Mr Yoshida?

Ichinose: Let me first discuss Japan's technology level for ceramics. During my visit to the United States in November last year, I found an article in the NEW YORK TIMES warning of the critical conditions in the U.S.-Japan trade war. It warned that the United States, after failing in trade wars with Japan in the sectors of automobiles and VTR's, might suffer likewise in the high technology sector of ceramics. They are watching Japanese moves very cautiously.

Of the two types of ceramics I mentioned before, Japan, I suppose, is favored in the electronic type of ceramics. To take ceramic base plate as an example, over 90 percent of the production of alumina used as the base plate of IC's is produced in Japan. This one example is sufficient evidence that Japan excels in this electronic type of ceramics, Japan may be favored, in particular, in sectors where manual dexterity in work is required.

A comparison I made on the strength of the ceramics industry of nations around the world at the request of Nikkei confirmed that Japan excels in the electronic type of ceramics. It also proved, however, that Japan is inferior in engineering ceramics, where the mechanical strength of ceramics is of concern.

At this juncture, some people have begun to doubt whether there is any science in ceramics. To be brief, the development of basic research on ceramics lags

behind that for metals, organic substances, and live materials. Ceramics are adulterated with many elements, and are not easily amenable to scientific treatment, and are lacking in scientific and technological approaches.

Yoshida: The technology level of Japan for metal compared with other nations is very advanced where structural materials as representative of raw materials, is concerned. This is demonstrated by the so-called trade war. Japanese metal technology has a feature that its technology for production and for facilities has developed parallel and in concert with the development of technologies for the control of microscopic structures. This development, gathering momentum, has attracted the attention of the world. Advanced research exclusively on metals has tentatively been settled and research is currently oriented to the improvement of quality and ensuring of quantity. Regions which have yet to be explored, on the other hand, are those of border areas involving such problems as bringing out various functions by changing the bonding state among different metals, combining metals and ceramics, and combining metals with materials of living things.

Combination of metals with materials of other advanced technologies is a very large area of research for the metallurgical researcher. That is, such metals as amorphous metals and multiple-layer composite superlattices serve as base metals, onto which are bonded, for example, biotechnological materials to bring out new functions. Developmental research in such areas has to be pushed in the coming years, and industrially advanced nations in this connection, I presume, are at the same level of captivity with the same concept in mind.

Miki: Now, let us proceed into details and discuss how to advance research at some length. I request that you discuss the problem of research involved in the sectors of metals, ceramics, and organic and polymer chemistries, including new electronic technologies required to set up high technology systems of space development, etc.

Aizawa: In organic chemistry, functional raw materials are being worked on frantically to put them to practical uses. Chemical corporations, however, have had a hard time finding ways to make practical use of the materials. Functional film of some polymers, meanwhile, is capable of separating substances dissolved in liquids and of separating gases. The technology of Japan for polymer films, in this connection, is at a fairly high level and the films are finding good markets. At a certain conference in Europe, they said that the science of membranes originated in Europe, its technology in the United States and its commercialization in Japan. Such being the case, functional raw materials are a very attractive research item for chemical corporations, though they pose difficulties in finding a market.

Functional raw materials have applications also in sensors. The term "sensor" originated from "senses" of the body. The sensor, just like our five senses, gathers information from the outside, which is usually converted to electrical signals. Sensors are of two types. One is a physical sensor which senses light and temperature. The other is a chemical sensor which catches chemical substances, the source of smell and taste. Inorganic raw materials, at present, are hardly available for catching chemical substances since it is difficult to

take up a special molecule from among the many occurring in the air. Organic raw materials, on the other hand, are relied on in great measure as functional materials which can take up such molecules and convert them to signals.

Production of sensors using this type of raw material is currently getting underway. Biological materials such as enzymes and antibodies of all such organic materials, are most distinguished in sorting out molecules.

The sensor that uses materials of living things as functional raw materials, and that is referred to as a biosensor has been partly put to practical use and is serving to determine the quantity of components in the blood, such as blood sugar and cholesterol. These represent fine examples of biological materials in practical use as functional raw materials in machines. These sensors, I believe, are a breakthrough to allow biological materials to develop and to play an increasingly significant role in the future.

Miki: Would you tell me about the development of raw materials of artificial organs and biological adaptability?

Aizawa: In the category of "special research" conducted by the Ministry of Education, research on biochemical raw materials, as one category, has been pushed for a fairly long period, and the relevant technology level of Japan is high. Experiments of, for example, artificial hearts in animals currently focus on the extension of the period in which the heart can function--1 year or so at present. With research on raw materials running parallel with that on the functioning of the artificial heart at present, problems confronting the researcher are the fundamental biological adaptability of materials, that is, the problem of how to modify the surface structures of raw materials made up largely of synthetic polymers for that purpose.

One approach to the problem is questioning the essential nature of the bioadaptability devising the practical design of the raw material. These run parallel, working their way while differing with one another. It is noteworthy that some Japanese researchers have the idea of coupling in alternating layers of two raw materials of different characteristics. Other scientists are engaged exclusively in synthetic polymers. Another notable trend is hybridization. Biological materials are introduced into a synthetic polymer as a constituent so as to produce a hybrid which displays improved bioadaptability.

As can be seen, the problem is being oriented to the essential nature of bioadaptability, on the basis of which the design of the raw material has to be carried out.

Miki: You said that experiences have not yet been fully streamlined as scientific knowledge, Professor Ichinose. How about research on that?

Ichinose: New materials exist in ceramics, but I believe it is hardly possible that a material which will revolutionize the industry will show up suddenly.

One prospect of ceramics is to provide new functions to materials by applying various new processing technologies. The latest processing technologies of ceramics are diverse. One is to bring about the amorphous state, as opposed to the crystalline state through rapid quenching. Another is to divide materials finely to give superfine particles. Some researchers are engaged in an attempt to bring out superlattice devices using ceramics. While the technology of lamination has already been used in substantial measure, these new technologies might not bear fruit before the turn of the century.

Diverse functions, I believe, should emerge from these. As for the sensor, research is moving ahead to see to what extent ceramics can work as a sensor. When the development of sensors is reviewed with respect to the five senses of the body, one finds that sensors for chemical properties, such as smell and taste, lag behind. Though these properties, conceivably, may not be amenable to ceramic sensors, substantial developmental efforts have been made, as seen in sensors for gases and for humidity.

It became evident, during a forum of concerned scholars the other day, that the development of sensors for smell, taste, etc., is behind. Though biological materials may, essentially, be required to complete this type of sensor, sensors of fairly good performance using ceramics are currently on the market. Let's take sensors for humidity [as published] for example. Some ceramics, you see, change their electrical resistances upon applying heat. Those sensors in which electrical resistance falls with rising humidity [as published] are referred to as thermistors. Other sensors produce electrical potential difference with applied pressure. The technology level of this type of sensor, based on such physical phenomena, is fairly high.

Where sensors for gases and smells are concerned, gases are absorbed when they come in contact with the surface of a ceramic sensor, which, thereupon, changes its electrical resistance. One major problem confronting the researcher these days is the development of a gas sensor which can prevent accidental gas explosions of propane and other gases supplied by the utility. Good sensors should block the accident before it occurs, but in actuality sensors with high selectivity for different gases are not yet available.

Sensors for taste, in turn, may not be created with ease using ceramic functions, but are conceivable using biological material functions. Plans have been suggested for setting up a committee for research on relevant problems under largely STA sponsorship. It is hoped that, by making the best of such ceramic raw materials, new functions can be devised and new areas of application be developed. The scale of the market may reach ¥1 trillion by 1990, whether it becomes big or small will be the problem.

Where application of ceramics in engines, another major area, is concerned, prospects for application in the immediate future are slim. One problem is the method of assessment of the product. That is, how to determine whether ceramic material is actually available for engines. This question commands the attention of every nation. Japan, for her part, is tackling the problem with vanity. It is a common view of researchers concerned that Japan has lagged appreciably behind other nations in technologies including assessment

technologies and various others. Government support, therefore, is keenly desired in order to quickly improve the technology.

Miki: The metal sector has problems of steel and rare metals, among other things. Would you tell me, Dr Yoshida, how research should be advanced in this sector, including the method of purifying rare metals and related problems?

Yoshida: Rare metals nonetheless occur in substantial amounts on the earth's surface, you know. These metals, so far used only sparingly, will henceforth play a more significant role, both in quantity and quality as materials for functions, I suppose. Two trends for metallic materials--structural and functional--are notable. One involves purification of metal elements to a greater degree and combinations of these elements. The other aims to make distinct the difference between the role assigned to the bulk and to the surface of metals.

The method of purification may conceivably involve use of plasma at high temperatures or the support of lasers. The relative function of the surface and the bulk of metal may be compared to that of the internal contents and external bark of a tree. Whereas the strength and role of the internal contents or internal trunk have been analyzed with extreme precision, on the basis of which the structure, functions, and optimum methods of production have been designed, research on the bark has some way to go toward completion. Metals, for example, have a faculty for recovery comparable to that of living things, when the surface function is damaged. The capacity of stainless steel to recover when rust has developed on its surface is well known, but there are many metals that exhibit similar properties. Even ordinary aluminum and steel are endowed with the capacity for recovery on their own. The problem involved for the future is, by advancing a step further, to impart certain new functions to the surface in addition to the above functions.

Namely, with the development of analysis of conditions and characteristics of the surface or surface layer of metals, it seems that research on the control of microscopic structures of metals will advance in the coming years through various chemical, physical, and mechanical means, with an eye on raw materials for superconductivity materials. One very simple method, for example, is injection of ions. This method brings out entirely new metals, surfaces, and surface layers in a nonthermal but mechanical equilibrium, a condition never seen before. This is in contrast to the conventional method for producing metals based on thermal equilibrium. This method currently permits perfect control of components and structures for a surface layer of thickness of the order of magnitude of 10° to 10^{2} angstroms. Steel also has a surface layer with a fine capacity for automatic recovery produced upon injection of certain ions. Another major area of research is to investigate the surface of metals for optimum functions in connection with coupling with ceramics and life materials.

Miki: Our institute is pushing research on the assessment of the remainder of life for chemical factories, bridges, etc., as part of the research on assessing the credibility of structural materials using the budget appropriated

from the funds for the promotion and adjustment of S&T. What do you think about this problem, Dr Yoshida?

Yoshida: The assessment of the remainder of life is of most importance. The question of how the condition and structure of an object are affected, as time elapses, by chemical, physical, and mechanical forces, which are closely intertwined has to be tackled in a comprehensive manner. Researchers tend to ignore research on the method of assessment in general. Where raw materials are concerned, the ultimate objective of research is the assessment of performance, on the basis of which one can advance to the next research. The three research sectors of designing, production, and assessment must be advanced through close cooperation.

Another very important property for a structural material is that it may suffer damage but must not be destroyed. Still another is the capacity for recycling. It is important for the metallurgist to be aware that recycling of a metal must be made a major part of research on the metal. Research of the assessment of recycling also is a major item.

Miki: We see that industry has a major share in the effort for the development of electronic and semiconductor materials. How about basic research in this connection, Dr Asanabe?

Asanabe: Memory devices, for example, are growing year after year. The figure is very favorable, but it also confronts us with the problem of how to deal with this growing trend.

Two problems may be involved. One is to produce silicon chips of larger size, a task for which raw materials makers are responsible. Up to the 4-inch size, the price grew proportionally with the size. It has been proved, however, that price grows much faster than size above 6 inches. This is a cause of great trouble not only for the user, but also for the maker in terms of technology, presently. Steel manufacturers, for their part, are embarking on the manufacture of silicon. They may well conclude that manufacture of silicon in small quantities, in comparison with that of steel in great blast furnaces, presents no difficulties. One feels that infusion of new blood might lead to the development of some new technologies and permit a breakthrough in technology, are given the competition among these manufacturers.

The electronics industry, in turn, places emphasis rather on thin films of crystals. At present, manufacturers generally seem able to control the material for each single atom layer. They actually are embarking on that process. Another problem involved, which is not a raw materials problem, is how to make an electrical contact of least electrical resistance, in small holes of a chip, as the size of the chip grows increasingly smaller. Increasing resistance of circuits with increasingly reduced dimensions is still another problem to be solved. In place of the gold and aluminum which have been used so far for wiring, titanium tungsten and other materials not easy to deal with have begun to be used. When these wires are attached to silicon or an insulation film, the interface conditions are not fully understood and, in films in particular, the phase diagrams for two element alloys currently used are not adapted to

their purpose. Research on various factors such as these needs to be advanced if a complete product is to be brought out.

Miki: We also see moves to make a diamond film to be used for semiconductors, don't we, Mr Asanabe?

Asanabe: That material is needed for the manufacture of fast computers. The fastest of supercomputers available, which are the fastest of all types of computers, this involves chips, each of which has around 1,000 gates, and the question is how to release the heat, around 10 watts, generated by the chips. The delay in speed of the computer is produced half by the device and half by the wiring and other packaged components.

Research on packaged components such as multiple layer ceramics needs to be pushed forward along with that on semiconductors. In that sense, diamond is excellent for heat conductance.

Ichinose: In terms of heat conductance, diamond films are superior to ordinary aluminum by two orders of magnitude. The currently available alumina base plates have problems in connection with the generation of heat by devices. Efforts, therefore, to produce base plate of better heat conductance have led to the creation of new ceramic units recently put on the market. One is silicon carbide, SiC, with a heat conductance around 10 times that of alumina. A power semiconductor apparatus using this plate has also been developed. Another is aluminum nitride, with a heat conductance seven to eight times--though not 10 times--that of alumina. Whereas these materials have heat conductances no more than 10 times that of alumina, diamond film raised the conductance strikingly by an effective two orders of magnitude, which has led to the brisk research of the film.

Miki: While we have been engaged in the development of raw materials, we have found that the so-called basic technologies such as providing ultimate physical conditions, technologies for the measurement of new raw materials, and needs for large equipment to implement measurements are growing in importance, as are individual research items. We have also investigated how to design raw materials as part of raw materials development. The Council of Technology for Aerospace and Electronics, for its part, is discussing such research items as creation of ambient conditions of superhigh pressures close to 100,000 atmospheres, of superhigh temperatures over 4,000°C, of super-vacuums, etc. It is also looking at creation of new raw materials and understanding phenomena by the use of X-rays and special neutron beams and other particles. Testing and assessments of ceramics is also of great importance. Allowing for these issues, what would you think are the future problems common to every sector of research, Mr Yoshida?

Yoshida: Our institute has, for a long time made it a rule to develop machines and equipment required for the research of raw materials. With these, measurements have been taken to determine the conditions and functions of materials, which may lead to the creation of new raw materials. Using an assortment of equipment ranging from an accelerator for ion injection into semiconductors and metals to a giant accelerator for nuclear physics, this

institute is prepared to work on any analysis and creation of material structures.

Increasing importance must be attached to the application of light, e.g., in the analysis and creation of materials, and creation of functions. With a view to diverse research using light, the institute has long been engaged in the development of lasers of every frequency, including high-capacity lasers, and has just become prepared to meet general requirements. With substantial research made and money spent, this successful result has been attained after a 10-year effort.

In Europe, research is allocated to each nation, i.e., Britain, France, etc., in the form of national facilities, continental facilities, etc., in an orderly way. I believe that Japan also must give priority in equipment investments when these are very expensive, as European nations have done. I suppose that this question must be taken up by the government in the case of raw materials research, as has been true in other sectors, where common basic technologies are involved. Fortunately, such a movement has begun.

Miki: We have seen that testing and assessment of materials is one major problem for ceramics. Would you discuss this and other problems which are common to all research on ceramics, Professor Ichinose?

Ichinose: In connection with the importance of assessments referred to, we note that recent technology for assessment and for analysis is using very large apparatuses. Universities don't seem to be able to afford a machine of several hundred million yen in value. However, without it, microscopic analysis is impossible. There is no denying that assessment of materials in ceramics is expensive, since various physical properties in ceramics cannot be analyzed, unless microscopic analysis is performed at the molecular level, and since comprehensive analysis is not possible without that. It is desired that large apparatuses be collected at one place and made available to researchers.

In ceramics, the boundary of grains, where grains maintain contact with each other, has a problem. That is, the destruction of a ceramic sometimes begins with the grain boundaries. The assessment of grain boundaries is an important technology, and apparatuses for that assessment are acutely desired. It is hoped that a study can be made at the government level to establish an analysis center in which such kinds of apparatuses are concentrated.

Another problem is related to data bases. Ceramics lacks knowledge in large measure in the area of raw materials design. By collecting various data, a data base must be streamlined as early as possible. This may be another evidence that research on basic science lags behind in Japan. Data bases, anyway, must be made complete.

Miki: It seems difficult to build up a data base for ceramics in a short time when such becomes necessary. Some systematic method of attacking the problem seems necessary, doesn't it?

Ichinose: It is also a fact that the process takes too long and does not give reliable data. The extreme difficulty in ceramics is due to the fact that entirely different properties emerge as the method of manufacture is varied. In alloys and polymers this kind of data base seems to be accomplished with relative ease, as opposed to ceramics.

Nevertheless, we cannot remain indefinitely in the stage of trial and error. We must go ahead with research on raw materials design in order to make the design possible. In that sense, we need to further study the problems in ceramics, even though a MITI committee, the Committee for the Study of Raw Materials Design (COMPAS) is also doing that task.

Miki: What do you think Professor Aizawa?

Aizawa: Organic substances and biological materials are extremely diverse and not amenable to simple generalization. One common thing in advanced technology may be control of raw materials at the molecular level. Protein engineering, in the case of biotechnology, is flourishing. It may be possible to see what protein structures are related to functions of living things if one observes precisely the protein formed by the living thing. If we can do that, we can work out a theory of designing molecules in which their functions are associated with their structures.

An enormous quantity of data, or an enormous data base at this point is needed to complete the theory and, for this purpose, experts are presently working frantically to build up the data. After one has established such a design theory, one can go ahead and design a new function of a protein which even living things lack, and then have a life system produce that protein on the basis of gene engineering. One can further design and produce other substances. This project, of course, requires a huge budget which single universities cannot afford. Unlike the projects of common interest for inorganic or metallic materials, this one involves very specific applications. It requires government support, to which it is entitled, for the purpose of raw materials manufacture in the biotechnology sector. Government support, I believe, is necessary not only for large machines and equipment but also for other facilities, for manpower, and for various expendables.

The manufacture of organic raw materials, where the manufacture of raw materials at the molecular level is an urgent problem, has the feature that beam technology is not always applicable. This implies that many of the organic molecules are unable to display their functions any longer when subjected to a vacuum, a condition which is commonly required in beam technology.

The major problem for organic substances is the technology of how to arrange molecules with precision at the molecular level. One method, long familiar to people, is to let one drop of a substance like oil fall on the surface of water and to allow the substance to spread over a large area of the surface. This phenomenon was used in Langmuir-Blodgett's technique (LB film, a technique developed by two scientists of GE, United States) which permits film of some substances to spread over the surface of water with precision at the molecular level. This film is scooped and transferred to the surface of solids where molecules arrange themselves to form a film.

This technique is currently in revival. With no other suitable technique available for producing thin films with precision at the molecular level, this method has come into the limelight. It was assumed that LB film has its molecules arranged in a regular manner, but it was not clear whether this regularity of molecules changes in the spreading surface of the film. This question was answered at the second international conference held recently in the United States. They argued that there are many defects, or more positively, that of necessity, there must be randomness in arrangement, and it has been proved that there are some parts which maintain regular arrangement of molecules and others which are amorphous. On this basis and with other facts, a new technology for producing film with precision at the molecular level has to be worked out.

The questions of how to measure a film of thickness approaching that of the molecule and how to determine the presence or absence of regularity of molecular arrangement are associated with the common basis of scientific research discussed earlier. The subject of measurement is for organic substances, moreover the methods of measurement available, therefore, are of necessity limited to a substantial extent.

The technology using light, or beam technology, at this point needs to be applied, and technologies to produce relevant apparatuses with precision at the molecular level are very important, although these have yet to be developed lacking the need for such thorough precision. A technology for assessing the product must run parallel with this. Neither an object for manufacture nor an almighty methodology for the product has been determined. However, the necessity for these is now felt keenly. The Ministry of Education added research on organic film to its special subjects of research 2 years ago where the same problems have been attacked.

In the case of semiconductors, we see technologies of arrangement with precision at the atomic level being reported one after another, but assessment of the product is an open question. In the organic chemistry sector, the condition is similar, with atoms replaced by molecules.

Miki: Would you please comment on this issue, Dr Asanabe?

Asanabe: The question of assessment may be divided into three categories. First, one assessment involves measurement of only one aspect of test specimens, hence, effective information is obtained only after various types of measurements with various expensive measuring instruments. It is important, therefore, to create an assessment instrument of multiple functions. However, a corporation would never fail to go bankrupt if it installed a set of measuring instruments of multiple functions for each raw material item under research. So some special measures need to be taken to deal with this difficulty.

Another problem is that assessment of very fine regions such as the microscopic is presently impossible. These regions are analogized by means of large TEG, etc., but their size effects have yet to be available. The number of atom layers actually formed cannot be known as well. Third, semiconductors are very vulnerable, as are the organic substances mentioned earlier, in that when, for

example, they are bombarded with high-energy particles, etc., in order to directly observe their features, they undergo entire changes in condition. I think that some new technology involving a softer probing agent needs to be created in order to observe them.

Miki: After having listened to all your views, I keenly feel again the importance of the role of the government in testing, assessing, streamlining facilities and data bases which must be available to all researchers, and in basic research.

These days we often speak of the cooperation of the government, academic circles and industry. Our agency also regards this cooperation as the basis for making budgetary allowances from the fund for the promotion and adjustment of S&T, observing the guidelines of the Council of Science and Technology, so that R&D with emphasis on raw materials, can advance. We are also reviewing various systems in this connection. The Ministry of Education and MITI are also making considerable efforts to promote joint research with cooperation of the government, academic circles, and industry, though substantial difficulties are involved. Would you discuss relevant government policies please?

Aizawa: The principle or idea of cooperation by the three is apparent but actual joint research seems difficult at present. Meetings for discussion may proceed smoothly, but I wonder whether joint work in which the advantage of each research partner are fully displayed is possible. Such joint works, put up as a slogan, may be put in order as research items, but I am afraid that the research is actually divided into many small groups and research results attained by each group are merely put in order. There must, of course, be successful cases. However, joint research in the true sense of the term seems to have to be reevaluated at this point.

Miki: STA, on the basis of a report submitted recently by the Ad Hoc Commission on Administrative Reforms, is engaged in preparation of a draft for an Act for the Promotion of Research Exchange with a view of pushing cooperation in research by the government, academic circles, and industry. It aims to promote joint research, which is unfettered from the existing research systems, exchange with other nations, open government research facilities to broader uses, and has concrete measures. The research project, Exploratory Research of Advanced Technology, has already achieved substantial results and is appreciated considerably by industry and other quarters.

Yoshida: Even if the government, academic circles, and industry may cooperate vertically, i.e., between superior and inferior organs, I doubt, however, whether they will do so horizontally, i.e., a government organ with an academic organ, etc. These relations seem precarious. This is the critical question. I believe that something like the disposition of researchers must underlie this problem, fundamentally, since it is generally true that the researcher does not welcome a research subject decided by others and imposed on him.

A researcher engaged in research on a subject which he does not prefer is merely doing simple labor. The decision, on his own, of the subject of research accounts for 80-90 percent of his total research. It is imperative that he be

willing to devote his life on the research work he has chosen. In this sense, the Fund for the Promotion and Adjustment of Science and Technology and the Exploratory Research of Advanced Technology Project both represent very subtle systems since both push joint research while preserving the factor of personal initiative to some extent.

It is important that the government make trial research systems involving various setups. It is desired that the government implement various types of research systems, while providing for large-scale apparatuses and facilities. A data bank also needs to be streamlined perfectly by the government. The government needs to engage itself always in tasks aimed at the most advanced--be it research subjects or research systems--while maintaining technologies in general at a fair level. Exchange of research should not be limited to the mere exchange of papers but be advanced to contacts in everyday life. It should not be restricted to just within Japan, but be extended to AC as opposed to EC. In addition, it is desired that the government give consideration to providing a place of research where all nations can take part in research which will support the next century. It seems that the time is now for a new system to be set up for international joint research allowing for the same activity of the past pushed ahead in substantial measure, though individually and not systematically.

Miki: I suppose efforts of private concerns weigh heavily on research on semiconductors and other electronic raw materials. How about your views on the cooperation of the three in this sector?

Asanabe: Our corporation has decided to build a research institute at a site where the Tsukuba World Expo was held. It is hoped that some close connections with government research organs, Tsukuba University, etc., may blossom soon because of its easy access to them. We plan to install equipment which is not yet available to them and to invite researchers for short periods which we hope will make a breakthrough.

Ichinose: It seems to me that the plan Dr Asanabe commented on is very similar to the concept of the research park which the United States has recently been implementing in reality. The park is a system where universities, corporations, and government research organs engage in concert in the exchange of information. It would be ideal if an analyzer were installed somewhere securely in the park, from which almost any data would be immediately available.

One problem to be resolved is that a researcher often changes by his site of research, from university to corporation, but only infrequently moves from corporation to university. No true exchange of information seems to exist unless this type of exchange is pushed ahead. It is hoped, therefore, that this type of exchange will be considered in drafting the Act for the Promotion of the Research Exchange.

Miki: We see various R&D programs being set up that extend toward the 21st century. The three Japanese astronauts chosen last August are slated to get on board the space shuttle in January 1988 to engage in various raw materials experiments there. About 1993, a U.S. space station is expected to be built

by the concerted effort of major participating nations. Japan, as one of these, plans to make experiments largely on raw materials in an experiment module. A number of groups in industry are currently applying themselves to work out a plan for their experiments. It is hoped that experiments on and manufactures of raw materials go on without delay and achieve many successful results.

It is also clear that so-called "frontier devices," i.e., molecular devices, biological devices, quantum effect devices, etc., are being developed as next generation devices. I request all of you finally, to tell me the vision or prospects of the 21st century, including these developments.

Yoshida: We are pressing ahead with a research task by the name of "frontier materials." The term material is applied to the area ranging from material to raw material and from material to life. There are, as you see, many "blank boxes" in raw materials. Many parts in biotechnology are dealt with merely as problems of input and output. Mechanisms of functions inside a cell still remain obscure. It is for the purpose of exploring this virgin soil that we call this research task "frontier materials."

This frontier material research involves many research subjects. One is the reaction of materials in plasma at high temperatures. Application of high pressure to this reaction is another subject, as is the application of a powerful magnetic field. High-pressure applications, in turn, may be made in various ways. For example, while large ingots are produced in a steel mill, a jewel is obtained from the ingot by placing a certain substance in the melt beforehand. This implies that various substances may be produced by applying heat and the pressure caused by thermal contraction.

We are, therefore, going to provide for various experimental conditions as we proceed with the exploration of materials. This exploration includes research on the structure, function, and mechanism of elementary devices as the basic unit where various functions of materials are manifested. Various processes must be traced and understood, for example, by combining a biological element to a superlattice structure and by applying to the product physical and mechanical processing, such as cutting. We are planning further to extend this study of the behavior of single unit elements to that of their agglomerates, and to control the latter as one comprehensive subject of research, including biotechnology.

We are going to examine biological functions further at the cellular level.

One tends to regard elementary devices as functional structures. However, it is possible that an ultimate single function is represented by a simple structure. By assuming elementary devices have such an ultimate single function, we like to consider functional devices as made up of various combination of these. This is the development from material to raw material, and from material to life, which we aim to explore. We regard development of the frontier device, the so-called functional device, as a by-product gained from broader research on "frontier materials." We are going to learn from nature and from life, including gene recombination from the facilities at Tsukuba, and thus to enter into research involving the manipulation of the structure of materials.

Aizawa: To learn from life is a problem of today as it always has been in the past, and presents new aspects to consider at all times. One example we always quote is the process of manufacture of the airplane. Formerly, they attempted to fly using wings quite similar to those of bats or birds. What they aimed at was, after all, the function of wings, the lifting force. People in former times may have started production of airplanes by imitating life, but they are now turning out quite a different thing.

This, perhaps, is the principle that engineering is to obey. Life sometimes achieves superb functions in terms of electronics, as it does so in comparison with artificial organs, etc. A researcher may take, in this connection, the attitude of just copying life at some stage of research. He then departs from this attitude, however, and creates things quite different, though with some similarity. This is very human wisdom, which must be attained, I suppose.

One current trend is the attempt to create a computer based on the function of the nerves and brain of man as the model. There is much here to learn, the study of which, however, needs to be advanced for two problems. One concerns software in the sense of programming, including that of the computer. The other concerns the hardware, where the subject of research is the raw material. Research on these two problems needs to run parallel.

It does not seem possible to attack molecules straightforward, such that one molecule could give one function simply by cleaving molecules to pieces. Though molecules ultimately may exhibit such functions, the tentative target, I think, must be to design molecules, and to allow them to function as an agglomerate.

In this connection, designing and producing an object is most advanced in organic molecules and in biological molecules like protein. Here, the theories on designing materials are expected to become much more advanced and prevalent, and permit various products to be created in simple ways. The question here is a raw material as the base functional unit. As I said before, technologies for manipulating such materials with accuracy at the molecular level will grow in importance.

In connection with the superlattice referred to by Mr Yoshida just now, the problem of laminating organic molecules into a product corresponding to the superlattice of inorganic molecules is being tackled in earnest. It would be a real breakthrough if such an attempt could lead to the development of a device with functions based on different principles from those for the device used in electronics. It seems to me that attacking organic materials with a view to reproduce functions which are now being displayed by semiconductors may not necessarily be a major historical current of scientific vision. In that sense, real importance must be attached to technology which permits manufacture of molecules with accuracy at the molecular level.

Miki: Would you please comment on this issue, Professor Ichinose?

Ichinose: I just agree with them. The sensor, which I talked about a little while ago, involves, after all, the problem of how closely one can imitate our

senses artificially. Scholars of various science sectors lately gathered and compared the performances of sensors. They concluded that the performances of sensors are far below those of natural senses even if some sensors may exhibit performances superior to those of natural senses. The only way to narrow the gap involved to any degree is still by learning from life. Biologists say that sensors for taste do not pose many difficult problems. They predict that a sensor may be completed in 5 to 10 years, perhaps by combining biochips with semiconductors.

Assuming that such a principle is available, the raw materials makers on the hardware side must make a positive approach to the problem. By coupling such biologists with makers of related hardware, the sensor for taste may be materialized in a time to come. I would like to aim at the target of that sensor in research extending toward the 21st century, even if the real target might be located at a different site from that of the target I aim at.

Yoshida: In the 21st century, science has worked its way so far by learning from the mechanisms of the human body and is still doing so. It seems that the relation of information and life involving entirely new mechanisms will come out from there.

When we think of raw materials, we are apt to direct our attention exclusively to electronics and the like as they relate to new materials and new devices. The human body, nevertheless, still has the action of catalysts and microbes from which we must learn. The raw materials also include catalysts and microbes which have very broad ranges and with which a researcher can begin his research.

Asanabe: In connection with biotechnology issues, we feel that we are reaching limits as far as microprocessing and software development are concerned. We have to learn from the functions of life whether we like it or not. The 21st century perhaps will see the merger of electronics and biotechnology, producing such new technologies as bioelectronics. Biotechnology now needs to embark ardently on exchanges with electronics.

I am almost sure that some of the present electronic technologies, for example, superfine processing and image sensors, must be conveniently available for enhanced understanding of biological functions. I would like to offer them to you to serve as part of your technology system. We also would like you to inform us of the results of the application of these technologies so that these results may serve as feedback for development of our technologies.

Miki: I much appreciate the valuable views you have given me here today. Now let us conclude today's meeting.

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NEW MATERIALS

ARRIVAL OF TITANIUM AGE, FUTURE APPLICATIONS DISCUSSED

Tokyo NIKKO MATERIALS in Japanese Jan 86 pp 13-16

[Article by Takashi Muro]

[Text] The research, development, and industrialization of titanium alloy have been carried out rapidly. Titanium is lightweight, resistant to rust and heat, and has high strength. Japan stands second in the world as a producer of sponge titanium, a raw material of titanium. With regard to putting this alloy to practical use, however, Japan has been outpaced by the West because it has not been profitable for Japanese material manufacturers to invest in research and development. In addition, these manufacturers have not had the demand for metallic materials for aircraft and space, so-called "high grade field" materials. At present, however, steel, nonferrous, titanium, metallic processing, and rolling manufacturers are waiting for an opportunity to branch into high grade field materials by successively investing in the development of titanium alloy or starting the industrialization of the metal, as a result of these manufacturers being influenced by the needs of the high-technology-oriented industrial world. It is anticipated that demand, except in the aircraft field, will be increased greatly in the 21st century, if function and potential are clarified successively.

Successive Branching Out

At present, the annual production capacity of sponge titanium throughout the world is about 130,000 tons. Of the 130,000 tons, Japan annually produces 34,000 tons of sponge titanium. Japan stands first in the free world in the production of sponge titanium, and has established this position over 30 years since producing sponge titanium was begun.

The specific gravity of titanium is 4.5, which is half that of copper and nickel. Titanium is lightweight, weighing 60 percent that of steel. In addition, the strength (specific strength) of titanium against its specific gravity is three times that of aluminum. Titanium has corrosion resistance equivalent to that of platinum. Titanium alloy is called "the third metal" after iron and aluminum, because it has cryogenic properties, non-magnetic properties, bioadaptability, and elastic characteristics. In particular, the main areas for producing titanium alloy are Brazil, India, Australia, and the Republic of South Africa; each of which have abundant resources.

Titanium alloy has the advantage of having the fourth largest amount of resources contained in the earth's crust behind aluminum, iron, and magnesium. It is a very promising metal except for the following two points: electric power is required for its manufacture, and it is difficult to work with because of its hardness.

At present, the line-up of sponge titanium manufacturers is as follows: Osaka Titanium Co., Ltd., Toho Titanium Co., Ltd., Nippon Soda Co., Ltd., Showa Titanium Co., Ltd., and Toyama Showa Denko K.K.; as well as stretching material and alloy manufacturers; steel blast furnace manufacturers such as Nippon Steel Corporation, Nippon Kokan K.K., Kobe Steel, Ltd., and Sumitomo Metal Industries, Ltd.; nonferrous metal manufacturers such as Nippon Mining Co., Ltd., Mitsubishi Metal Corporation, and Furukawa Electric Co., Ltd.; and special steel manufacturers such as Daido Steel Co., Ltd. and Hitachi Metals, Ltd. Of these manufacturers, the companies which have entered the sponge titanium field over the past 3 years are Nippon Steel Corporation, Nippon Kokan K.K., Showa Titanium Co., Ltd., and Toyama Showa Denko K.K. With regard to the production and industrialization of sponge titanium, Mitsubishi Metal Corporation has given up a joint business plan with Westinghouse Electric Corp. in the United States, but has carried out a feasibility study of joint enterprise with other companies in the West. Also, Mitsubishi Metal Corporation has suggested a business expansion if sponge titanium can be produced with lower electric power costs than that in Japan.

Greatly Expanding Use

Looking at a field in which titanium materials presently being produced are used, most of them are used in the industrial field.

For example, capacitors made of titanium have been adopted successively in nuclear and thermoelectric power plants by the electric power industry since Kobe Steel, Ltd. operated such capacitors in Amagasaki and Kakogawa plants, respectively, which are in-house power plants. In particular, the amount of titanium used per capacitor in a nuclear power plant is 150 tons or more.

In addition, titanium has been used in heat exchangers and fractionators in petroleum refineries. Titanium is becoming an indispensable substance for high-technology uses such as steam turbine blades in power plants, nuclear fuel reprocessing units, heat exchangers employing a sea-thermal power generation system, LNG (liquefied natural gas) vaporizers, seawater desalinators, chemical fertilizer plants, electrolytic industry, automobile engine parts, cryogenic structural materials related to super-conductivity, and other energy fields.

In particular, the adoption of industrial titanium has greatly developed fields in which water resources such as seawater treatment, cooling systems by using seawater, etc., are used, and has already brought about large cost reductions in many fields.

Titanium is an element not contained in seawater, and is also resistant to seawater. Recently, underwater robots, deep submergible vehicles, etc., have been developed and put to practical use. They are used to survey the seabed and deep sea in ocean development projects. Titanium is indispensable as a structural material which can withstand hydraulic pressure. With regard to military use, titanium has already been used in nuclear-powered submarines. Technology concerning titanium has recently been adopted to private and industrial investigation ships.

The use of titanium has been started in various private fields. For example, titanium is used in the frame of glasses, body materials for clocks, cameras, fountain pens, golf club shafts, automobile body and frame, mountain-climbing equipment, tennis rackets, and winterized skiwear.

As shown above, titanium is used with consideration to its characteristics such as hardness, absorption of impacts, etc., and there is no doubt that it is used in various fields, compared with iron and aluminum.

Biofunctional materials, such as artificial tooth roots and artificial bones, also have come into the limelight. Several companies, such as Furukawa Electric Co., Ltd., have already offered pure titanium artificial tooth roots to clinical demonstrations since last year. These artificial tooth roots are commercialized in the form of a titanium shape-memory alloy or titanium plus ceramics.

Progressive Technology for Practical Use

The types of titanium alloy have increased continuously. For example, nickel-titanium alloy is a shape-memory alloy, niobium-titanium alloy is a super-conductive material, and titanium-iron alloy and titanium-manganese alloy are metallic alloy materials for hydrogen storage. Research on respective alloys has been conducted, and new methods of molding and processing these alloys have been considered with a view to enhancing the characteristics of these alloys. Research on superplastic alloy and cryogenic alloy and trial-manufacturing of high-temperature titanium-aluminum alloy have been carried out enthusiastically. These alloys, however, have not yet been put to practical use.

The National Research Institute for Metals of the Science and Technology Agency is presently conducting research on titanium alloy as a cryogenic material and high-temperature titanium alloy as an aircraft material, in parallel with the work of manufacturing titanium alloy based on powder metallurgy.

As a result of conducting research on titanium alloy as a cryogenic material, titanium alloy with about twice the fracture toughness value of conventional titanium alloy has been put to practical use.

Titanium alloy has a beta-phase and an alpha-phase. The former is stable at high temperatures, and the latter is stable at low temperatures. When both phases are heat-treated, they will change. When the cooling speed after

heating the beta-phase is changed, toughness will become different from that of the alpha-phase. The above institute has succeeded in giving high toughness to titanium alloy by using the above feature, i.e., by cooling the titanium alloy on the basis of the specified control method after heating it to its beta-phase. It has been confirmed that the fracture toughness value at liquid helium temperature of -269°C is 85 MPa m^2 (270 kilogram-force per square millimeter), which is a value at a yield strength of about 1,500 MPa m^2 (150 kilogram-force per square millimeter).

Conventionally, the ELI (extra-low interstitial), i.e., extreme reduction in density of interstitial elements, has been indispensable for enhancing the toughness of titanium alloy, and the only alpha-alloy has been optimum at low temperatures, because it has little ductility at low temperatures. However, the above figures have surpassed this. The value obtained as a result of conducting research and development of high-temperature titanium alloy has cleared the value desired for carrying out development of the alloy at the alloy design stage.

Titanium alloy has the highest specific strength (strength/specific gravity) at a temperature of around 300°C in the practical alloys. For this reason, it is said that titanium alloy is optimum for aircraft engine materials used at this temperature. Research and development of a lightweight and tough alloy based on superplastic-worked titanium has been taken as a theme of the Research and Development Project of Basic Technologies for Future Industries. Materials focused on the above fact will be put to practical use.

The titanium alloy being used most frequently at present is a vanadium alloy consisting of 60 percent titanium and 40 percent aluminum. When the organization, deformation temperature, and deformation velocity are matched with the specified conditions, the vanadium alloy will exhibit superplasticity, that is, its elongation will reach 1,000 percent. But it has the disadvantage of its strength being low. In order to solve this drawback, the vanadium alloy must be designed with consideration to the following points: 1) the vanadium alloy must have a specific strength of more than 28 kilogram-force per square millimeter at a temperature of 300°C; 2) the elongation must be more than 10 percent; and 3) the value of working yield must be more than three times that according to a conventional method (the conventional method means that parts are manufactured by cutting forged materials).

Research and development of new alloys (GT-32 to 34) have been carried out thus far so they can have a high alloy strength by lowering the set working temperature from 900°C to 850°C, and by increasing the amount of reinforced elements such as molybdenum, chrome, and iron, added to these new alloys while keeping the ratio of alpha-phase to beta-phase at 1:1. The GT-33 alloy consists of 6.5 percent aluminum, 1.4 percent vanadium, 1.4 percent tin, 1.0 percent zinc, 2.1 percent molybdenum, 2.1 percent chrome, 1.7 percent iron, and 83.8 percent titanium. In particular, this alloy shows the alloy strength value which exceedingly surpasses the desired value. It also shows superplasticity of about 700 percent elongation at a temperature of 850°C. In addition, it can be superplastic-worked smoothly, because the maximum deformation stress is extremely low, being 1.3 kilogram-force per square millimeter.

On the other hand, the Titanium Technology Committee has been carrying out research and investigation on new alloys, including chemical compounds, in collaboration with the industrial world since the Super-titanium Alloy Subcommittee was established in the committee with a view to conducting research on lightweight and high-heat resistant titanium-aluminum base alloy as a space and aircraft lightweight metallic material. Also, the National Research Institute for Metals has manufactured various articles on an experimental basis. At present, the temperature limit of aluminum alloy is 250°C, and that of titanium alloy is about 500°C. In the case of higher temperatures, heavy metals such as iron base alloy, nickel base alloy, etc., must be used. Also, the temperature limit of normal titanium alloy is 600°C, however, the alloy may be devised.

The intermetallic compound titanium-aluminum is combined at a ratio of titanium atoms to aluminum atoms 1:1. But the specific gravity of the titanium-aluminum alloy is light, being 3.6, and has a higher strength than that of nickel alloy even at temperatures of more than 900°C. The alloy based on this metal is called "high-heat resistant titanium alloy," but it has not yet been put to practical use because it has weak points in workability and brittleness.

Thirty percent of the atoms constituting titanium-aluminum alloy are covalently bonded with each other in the same way as ceramics, and the remaining 70 percent of the atoms (with metallic characteristics) are metallically bonded with each other. For this reason, it can be considered possible to utilize titanium-aluminum alloy in the future by using a technology called "Extension of General Metallic Material Working Technology." Titanium-aluminum alloy is in the limelight as a lightweight material for rocket engines, etc., and its development is being carried out.

Aiming for New Metal Age

The National Research Institute for Metals has succeeded in experimentally manufacturing high-quality titanium-aluminum alloy without any contamination at pots together with high-purity lime pots in vacuum high-frequency smelting furnaces. This manufacturing method was carried out by using the titanium-aluminum alloy manufacturing method, which is a technology generalized instead of the vacuum arc melting method. As a result, it is expected that the cost can be reduced greatly. Also, the development of the following methods has been started: the manufacturing of bar materials according to a lateral pressure-additional extrusion method, manufacturing of plates by using cobalt base alloy as a sheath material according to a low-speed hot-rolling method, and manufacturing of isothermal forging materials by using ceramic dies. Hitachi Metals, Ltd. has succeeded in developing a super-plastic high-temperature die material, and has just opened the way for isothermal forging technologies. As a result, problems on insufficient working technology have gradually been solved.

In addition, it has been confirmed that titanium-aluminum base alloy has 3 percent cold tensile ductility. This alloy consists of 33 percent titanium, 3 percent aluminum, and 64 percent manganese alloy. As a result,

the National Research Institute for Metals has obtained titanium-aluminum base alloy, lightweight, high-heat resistant materials with more than 10 percent tensile ductility at temperatures greater than 800°C, a yield strength of about 40 kilogram-force per square millimeter, and a yield strength of 20 kilogram-force per square millimeter even at temperatures up to 1,050°C. Future research will focus on workability and toughness.

A superconductive field has been promoted rapidly. Niobium-titanium alloy containing 40-70 percent titanium is a super-conductive material which has been most put to practical use. It is used for linear motor cars, particle accelerators, tokamak type nuclear fusion reactors, NMR-CT (nuclear magnetic resonance computer tomography), etc. At present, the copper matrix is used as a stabilizer. Strong workability can be obtained by linearizing this matrix. For this reason, it is said to be a more useful material than any other, but it has the disadvantage of superconductivity being slightly lower than that of other materials. Research on high-magnetic field characteristics is being conducted to solve this problem. High-magnetic field characteristics can be obtained by adding tantalum and hafnium to niobium-titanium alloy within a range in which workability is not lost. With regard to niobium-titanium base alloy wires to which heavy metal is added, the National Research Institute for Metals has already succeeded in obtaining high-magnetic field characteristics equal to those of niobium 3 tin. In particular, niobium-titanium-hafnium alloy wires to which hafnium is added, are used for super-conductive magnets installed in university research institutes. Shape-memory alloys and metallic alloys for hydrogen storage have recently been put to practical use.

With regard to shape-memory alloys, when a powder metallurgy method is used together with a HIP (hot isostatic pressing) method with a view to manufacturing titanium-nickel alloys, their quality and strength will be almost equal to those of titanium-nickel alloys manufactured by using a smelting method. The powder metallurgy method means that both metals, titanium and nickel, are powdered and manufactured as an alloy by heating and sintering the titanium and nickel at a high temperature. In the HIP method an isostatic pressure of more than 2,000 millibars is applied to the metals. It is anticipated that mass-production of titanium-nickel alloys will proceed rapidly in the future.

On the other hand, with regard to metallic alloys for hydrogen storage, research on control of alloy shape, micro-capsulization, and ease of use has been conducted. Metallic alloys for hydrogen storage have been put to practical use since the alloy itself was discovered. Metallic alloys for hydrogen storage are used in air-conditioning systems, and the development of equipment employing such alloys is being carried out enthusiastically. At present, shape-memory alloys are used as materials or parts in artificial tooth roots, coffee mills, etc. The key to the spread of these new alloys into high-technology and private fields is to reduce the cost. There is a strong possibility, however, of these new alloys spreading into these fields at considerably fast speed, due to improvement of manufacturer's production technologies and the spread of powder metallurgy into the fields.

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NEW MATERIALS

RECENT TRENDS IN CERAMIC SOLID STATE DEVICES

Tokyo CERAMICS JAPAN in Japanese Jan 86 pp 3-8

[Article by Noboru Ichinose, School of Science and Engineering, Waseda University]

[Text] 1. Introduction

Research and development of electronic materials is the basis for advancement in the electronics industry. It is of increasing importance. In particular, given the current international environment that surrounds Japan, it is an urgent necessity that Japan carry out independent research and development on new electronic materials technology, and use the results in device making.

However, speaking of electronic materials, it is rare that a material exists already which precisely matches some specific utilization purpose in electronics. With some practical needs already existing, a research is made for a material possessing properties that satisfy the specified objects and conditions. In fact, it is rather more frequent that one has to endeavor to modify the properties of a material to suit the object one has in mind. This is what may be called "needs-oriented" research and development.

On the other hand, in the process of carrying out this research and development, it may happen that one accidentally discovers a material that exhibits new properties. In such a case, it is necessary to think about the possibility of creating a new part or device that makes use of the new properties. In addition, it may become possible to improve markedly the performance of existing parts or devices by taking advantage of such properties. Pursuing such is what may be called "seeds-oriented" research and development.

In either approach, the researcher or engineer has to maintain at all times a wide and deep understanding of the various concepts and phenomena in the fundamental scientific field related to the materials. In addition, in order to be able to connect these concepts and phenomena to actual accomplishments, it is necessary to carry out uninterrupted development parallel, with manufacturing and related technologies.

For devices in the electronics field, the mainstream is solid-state materials, although gaseous- and liquid-state materials are also actually used. In

solid-state materials, in addition to single crystals (solids whose specimen has a complete periodicity of atomic disposition throughout) materials, there are ceramic (small aggregates of single crystals) materials and amorphous (solids in which no periodicity of atomic disposition is recognizable) materials. In the present general survey, the main intention is to present a description from the standpoint of applying ceramics to solid-state devices. However, single crystals and amorphous materials will also be presented, included in the ceramic materials.

The solid-state devices that are related to ceramics are spread over wide areas. Here, devices related to microelectronics, optoelectronics, displays, sensors, and mechatronics will be touched upon.

2. Microelectronic Devices

Microelectronics, when translated into Japanese, becomes "minute circuit technology." Confining oneself just to hardware technology, take the computer as an example that enjoys directly the benefit of microelectronics. As may be seen from the first generation, vacuum tubes, (size: 10°, where relative representaton is used in which the unit of size of one logic gate due to vacuum tubes is called "1") the second generation, transistors, (size: 10^{-2}), the third generation, IC's (size: 10^{-4}), and the fourth generation, LSI and VLSI devices, (size: 10^{-6}), miniaturization proceeded rapidly, on the order of 10^{-2}. However, if miniaturization in hardware alone is of interest, it simply represents an extension of advancement of prior technology, which is not worth special concern.

Microelectronics means, in a narrow sense, minute circuit technology, that is, highly integrated circuit technology. In a larger sense, however, it is accepted by expanding it to include computers that blossomed through microelectronics, and applied technology of computers and digital technology in general. In particular, the largest impact brought about by the technology is regarded to be microprocessor technology.

Here, let us focus our attention on the peculiar characteristics of microprocessor technology, or, more generally, electronic digital technology. One must admit that technology affects the technical field and also fundamental human values. Namely, it affects political, economic, labor, and even ethical and moral values and in fact it is altering our world view itself.

At present, microcomputer technology is considered to represent an extension of human functions, that is, expansion of our spiritual capability and complementation of our intellectual activities. In other words, a small-sized microprocessor with intellectual judgment functions is easily available everywhere, and at low cost, for personal use as a "counterpart" for ourselves. This is a kind of "artificial intelligence." It has a revolutionary impact on the "software aspects" of human beings and the realization of expansion of human capabilities.

That the important solid-state devices related to microelectronics are the semiconductor devices centered around silicon (Si) is beyond dispute.

However, the development of related devices is also very important. Among devices being developed toward "light and small," there are packaged parts, chip parts, and microwave parts that will become indispensable in satellite broadcasting in the future. Further, magnetic parts that make use of super high-performance magnets are important. These will be touched upon in what follows.

First, ceramic substrates used for packaged parts will be mentioned. In place of existing alumina (Al_2O_3) substrates, development of new substrates has been active, seeking high performance and low costs. Among these, what is attracting attention are ceramics of the $BaSn(BO_3)_2$ system and the alumina-glass system as substrates sintered at low temperatures, and ceramics of the SiC-BeO system and the AlN system, as highly conductive substrates. As a result of development of highly conductive substrates, high-output semiconductor devices are appearing.

As a representative example of chip parts, one may mention surface acoustic wave (SAW) devices. SAW devices include filters and delay lines. However, filters are being used in larger quantities so that the following description will be limited to filters. A SAW filter is a piezoelectric filter that utilizes surface waves. Its resonance frequency is determined by the separation between the electrodes of the interdigital electrode. As shown in Figure 1, SAW filters are suited for use in high frequencies, and may be used in bands above Ghz. As piezoelectric substrates for filters, use is made of piezoelectric single crystals such as lithium niobate ($LiNbO_3$) and lithium tantalate ($LiTaO_3$), piezoelectric films such as zinc oxide (ZnO) and aluminum nitride (AlN), and piezoelectric ceramics such as the PZT system and $PbTiO_3$. However, aiming at high performance, new crystals such as lithium borate ($Li_2B_4O_7$) are being examined. At present, SAW filters are being used in large quantities in TV's and VTR's.

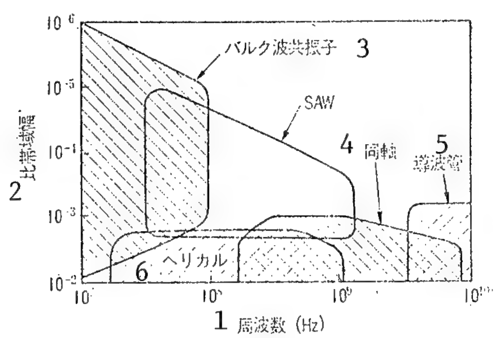

Figure 1. Application Regions for Various Kinds of Resonance-Type Filters

Key:
1. Frequency (Hz)
2. Relative band width
3. Bulk wave resonator
4. Coaxial
5. Waveguide
6. Helical

As a new technology in this field, single crystal ZnO film that is epitaxially grown on sapphire is expected to become a substrate material with the possibility of being unified with active elements in the future. These elements are applied singly or as hybrid parts integrated with circuit elements, to local oscillators for CATV, FM demodulators for satellite broadcast receivers, 900 MHz IF filters for high-performance tuners, front-end filters for automobile telephones, timing filters for optical digital transmission, and so forth, achieving high performance and miniaturization of systems and apparatus.

Application of dielectric materials to the microwave (several to 20 GHz) band has long been attempted. However, because of the inappropriateness of the temperature coefficient of the permittivity of the materials, the attempts have never been successful. These promising materials have been attracting attention since 1980, as a result of stimulation of research in the field by recent advances in microwave technology, and the expansion of demands. With the use of automobile telephones and the opening of satellite broadcasting, microwave devices that make use of (Zr, Sn) TiO_4 system and $Ba(Zn_{1/3}Ta_{2/3})O_3$- $Ba(Zn_{1/3}Nb_{2/3})O_3$ system ceramics are being put into practice.

Advances in performance of permanent magnets are truly remarkable. Figure 2 shows the development of energy products for permanent magnets. As may be seen from the figure, the recently developed Nd-Fe-B system ($Nd_2Fe_{14}B$) magnet has already achieved 370 kJ/m³ (about 45 MGOe) in the laboratory. Among the many materials for permanent magnets, Nd-Fe-B system magnets will have a heavy impact on the magnet devices in coming years of lightweight, small-size devices.

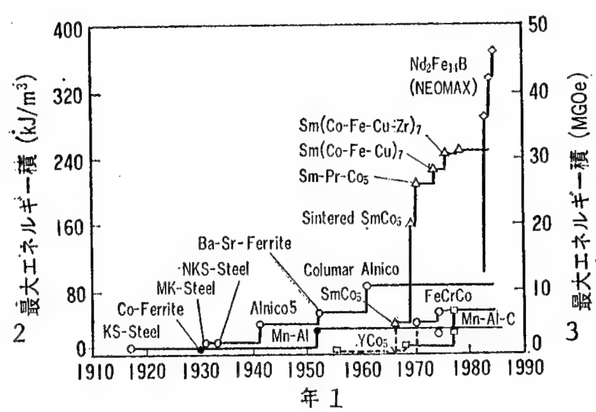

Figure 2. Development of Energy Products for Permanent Magnets

Key:
1. Year
2. Maximum energy product (kJ/M³)
3. Maximum energy product (MGOe)

3. Optoelectronic Devices

What is meant by optoelectronics varies from person to person and from time to time. A generally accepted definition at the present time is as follows:

The S&T and equipment that will replace functions formerly defined as electronics and the S&T and equipment that will replace functions formerly defined as optics. [as published]

Apparatus and technology, and the science, that will replace functions played in the past by optics by the means and methods of electronics.

These two fields constitute optoelectronics. Since they represent adjacent fields, one characteristic feature is that the boundary between them in changing constantly.

Examples of functions and devices that come to mind when optoelectronics is viewed from the broad definition given earlier are summarized in Table 1. Using these materials and devices, numerous apparatus and systems have already been put to practice or are under development. Representative fields of application include optical communications, optical information processing, image recording, display and instrumentation, and so forth.

In optoelectronics, various devices are used as shown in Table 1, and a wide range of materials are used accordingly. The common property in these materials is, needless to say, that light plays the principal role. Useful phenomena that are generated in the process of interaction among matter, light, and electrons are utilized as devices.

Table 1. Examples of Optoelectronic Devices

Function	Device
1. Light Emission and Display	Various kinds of lasers, light-emitting diodes, light-emitting devices by nonlinear optics, CRT, plasma displays, liquid-crystal displays, EL displays, others
2. Photoelectric Conversion	Photoelectric tubes, photomultiplier tubes, light-receiving diodes, photoconductive elements, image pickup devices, optical sensor arrays, others
3. Light Control	Optoelectronic and optoacoustic devices, functional elements such as amplification, coupling, branching, filtering, isolation, logic, light, optical integrated circuits, others
4. Light Transmission	Optical fibers, peripheral elements, others
5. Light Recording	Photosensitive materials, optical memories, others.

First, among phenomena that are generated upon irradiation of matter by light, fundamental ones are reflection, refraction, and absorption. The reflection factor, index of refraction, and absorption factor that represent the parameters for describing the phenomena are, respectively, the functions of the state of matter. By interacting with the state of matter from outside, or by creating appropriate combinations of matter that are in different states, it is possible to add information on light reradiated from matter. Most of the devices for optical regulation and optical transmission operate based on this principle.

Optical fibers are devices that make clever use of total reflection phenomenon. Transmitting light from one spot to another desired spot may be regarded, by itself, to represent "information." Although quartz and multicomponent glass are being used at present as glass for optical fibers, fluoride glass

(ZrF_4-ThF_4-BaF_2) with zirconium fluoride (ZrF_4) as the main constituent are considered promising. If optical fibers can be manufactured using such glass, it will become possible to attain a transmission loss of 0.01 to 0.001 dB/km, which is far smaller than the limiting transmission loss of 0.2 dB/km that is being achieved by quartz-based glass fibers. Therefore, expections for this new type of glass for future use are very high.

When light enters matter, a part of its optical energy is absorbed by the matter. This absorption generates some kind of change in the matter. Representative of such changes are the external and internal photoelectronic effects in which light energy is converted to electron energy. Optical conversion devices are those that take out the changes in the electronic state as electrical signals. On the other hand, in phosphors or various kinds of lasers that are pumped by light, light with a wavelength which is different from that of incident light is emitted when the excited electronic system returns to a low energy state.

In addition, devices that make use of transparent ceramics, such as applying alumina to light-emitting tubes for high-voltage sodium lamps, based on its heat-resistant, transparent corrosion-resistant, and low-cost properties, and the application of PLZT ($PbTiO_3$-$PbZrO_3$-La_2O_3) ceramics that utilizes electro-optical effects to light switches, etc., are being watched with favor.

4. Display Devices

An electronic display device may be defined as man-machine-interface, as an electronic device which transmits various kinds of information from various kinds of apparatus (machines) to the human being (man), and the bridges (interface) or connects man and machine. Therefore, the role of electronic display devices in the information society is very important, and their development will continue incessantly into the future.

Classification of electronic display devices is presented in Table 2. In the table, the case of displaying optical information signals by light emission is the light-emission type display. On the other hand, the case of controlling surrounding light by means of reflection, scattering, interference phenomena and the like, that is, display by means of light modulation, is the light-reception type display. Display devices that use ceramics include ECD and EL which will be described in what follows.

Electrochromism is a reversible color presentation and light emission phenomenon which is caused by creation and annihilation of color presenting molecules by the Stark effect, color center, electrodeposition, and electrode reaction. However, it may also be expressed simply as a "phenomenon in which the color of matter changes in reversible manner by oxidation and reduction reactions due to the impressions of voltage." The display elements that utilize such phenomenon are called electrochromic display elements (ECD). [In Table 2, ECD stands for "electrochemical display."] Given that colors are clear, the field of view is wide, has a memory function, can have multicolor displays, requires low power consumption, and so on, ECD is expected to make advancements similar to liquid-crystal display (LCD) elements. Research on ECD has been

pushed vigorously in the past, but there is as yet no device superior to WO_3 film. Recent trends in research are to understand and relate film formation conditions for WO_3 to its color presentation mechanism.

Table 2. Classification of Electronic Display Devices

- 1 電子ディスプレイデバイス
  - 2 発光型
    - CRT(cathode ray tube : Cathode ray tubes
    - PDP(plasma display panel : Plasma display panels
    - ELD(electroluminescent display : Electroluminescent displays
    - VFD(vacuum fluorescent display : Fluorescent display tubes
    - LED(light emitting diode : Light-emitting diodes
  - 3 受光型
    - LCD(liquid crystal display : Liquid-crystal displays
    - ECD(electrochemical display : Electrochemical displays
    - EPID(electrophoretic image display : Electrophoresis displays
    - SPD(suspended particle display : Dispersed-particle orientation type displays
    - TBD(twisting ball display : Tinted-particle rotation type displays
    - PLZT(transparent ceramics display : PLZT displays

Key:

1. Electronic Display Devices
2. Light-Emitting Types
3. Light-Receiving Types

The principal tasks for ECD are to lengthen its operating life and realize a matrix representation for large-capacity displays. One may say that putting ECD to practice can be promoted only after these tasks have been resolved.

Light emission caused by an electric field is called electroluminescence (EL). Included in it are genuine EL in which light is emitted from a phosphor such as zinc sulfide (ZnS), and the charge-injection type light emission such as that of a light-emitting diode. The genuine EL may be classified into dispersed-type EL, in which ZnS powder is dispersed in a binder with a high dielectric constant, and thin-film type EL, in which an element is formed by making a thin film out of a phosphor or insulator by means of vapor deposition. In addition, there are single-crystal types, ceramic types, and others. Also, depending upon the system of driving, they may be classified into AC type and DC type.

Although EL has a long history of development, research on it has been stagnant for some time due to insurmountable barriers in connection with luminosity and life. However, EL is under watch again after recent announcement by Bell Laboratories in the United States of a thin-film type element called (lumosen) [phonetic] which is seemingly able to provide high luminosity and multicolor, and attainment of high luminosity and long life by a thin-film type element that has double insulation layers developed by Sharp Corp.

5. Sensor Devices

Sensor devices are elements which measure physical quantities by means of some kind of conversion function. Sensor electronics is a series of electronics technology which processes information obtained from objects, and controls a portion of a process or system.

In sensor electronics, it is attempted to let electronics carry out amplification of the function, namely, the intelligence, of human beings. Man receives signals from the external world through his five senses (vision, hearing, touch, smell, and taste), transmits them to the brain, and issues a command after processing the signals in the brain. When this mechanism is carried out by electronics, the brain is replaced by electronic circuits, namely, a computer, which may be called an artificial brain. The five senses are replaced by senses, which may be called artificial senses. The sensors that correspond to the five senses have been developed as shown in Table 3. Although there are some sensors that surpass the capabilities of the five human senses when examined from a single function point of view, the overall capabilities are far behind those of the five senses. Much more must be learned from living bodies. The development aims of the sensors are to make them multifunctional and to integrate them, that is, make them smart enough and intelligent enough. In other words, these sensor devices must be functional sensors that are equipped with signal processing and feedback functions.

In a functional sensor, more than two functions may be assigned to one electronic device, or by the use of a plurality of elements, when some of the functions break down during the operation, the function can be taken over by a nearby element. In other words, this is a functional element that possesses so-called self-recovering or self-diagnosing capabilities. This is perhaps an ideal sensor, one that uses the cells of living bodies and their information transmitting system as its model. Realization of such a sensor may take 10 years or even more. However, materials for the sensors, amorphous semiconductors, liquid semiconductors, and organic semiconductors are thought to be promising. In other words, these materials do not have a regular organization in comparison to single crystals, and have higher internally accumulated energy than crystals. Thus, even if part of the organization is destroyed, there is a possibility of recovering on its own, thermally. With understanding of the fields of biophysical and electronic engineering of living bodies, sensors may see toward the 21st century an era of so-called molecular electronics elements which use these raw materials.

Table 3. Sensing Organs and Various Sensors

Sensing Organ	Corresponding Sensor		Principle of Use
Eye (Vision)	Optical sensor	Semiconductor sensor CCD sensor	Photoconductive effect
		Photo-transistor	Photoelectric effect
		Photomultiplier tube	Photoelectron emission effect
Ear (Hearing)	Pressure sensor	Electret	Distortion effect
		Ceramic sensor	Piezoelectric effect
		Microphone	Capacity change
Skin (Touch)	Pressure sensor	Semiconductor sensor	Distortion effect
		Elastic sensor	Capacity change
	Temperature sensor	Thermister	Resistance change
		Thermocouple	Seebeck effect
		Si transistor	Special heat change
Nose (Smell)	Gas sensor	Semiconductor sensor Surface-potential type sensor	Adsorption effect
		Combustion type sensor Electrolytic sensor	Chemical reaction
		Solid-electrolytic sensor	Membrane selective transmission
Tongue (Taste)	Taste sensor	(ion sensor) (enzyme sensor) (microbiological sensor) (immunological sensor)	

6. Mechatronics Devices

One mechatronics device is the actuator. Recently, piezoelectric actuators that employ laminated-type piezoelectric materials are becoming a conversation piece. Recent years have produced the laminated-type piezoelectric body, utilizing the technique for laminated ceramic capacitors, in which multilayered ceramic is obtained, with a thickness of 250 μm or less for each layer, and polarization processing given to each layer, so as to have opposite polarization direction to adjacent layers. With an element of 25 mm in length, it was possible to produce a large distortion that reaches 25 μm under application of minor voltage as 250 V. Moreover, it has excellent reproducibility and temperature stability. Through further reductions in thickness per layer, voltage that is required for a total displacement of 25 μm could be made less than 40 V.

Application of laminated piezoelectric ceramics that can produce large displacements to minute displacement elements, fast displacement elements, and

pressure generating elements is underway. One example is the application to the printer head. This utilizes elongation distortion (about 8 μm) of a small-sized piezoelectric actuator. Compared with the electromagnetic-type printer head, it has special features that the printing function is several times faster, consumed power is small by one order of magnitude, and the noise in printing can be suppressed to a large extent.

As a novelty we could mention an ultrasonic motor. Compared with the conventional motor that makes use of electromagnetic phenomena, an ultrasonic motor has a simpler structure and it is possible to make it small in size and light in weight for identical output. Moreover, electromagentic noise will not be generated because it makes no use of winding. Figure 3 shows the principle of a piezoelectric ultrasonic motor. By giving oscillation to the oscillator piece attached to the PZT oscillator, the rotor is driven and rotated by displacement in oscillation. The motor has already been trially manufactured toward putting it to use. Among ultrasonic motors, a surface-wave type that makes use of surface waves is being examined.

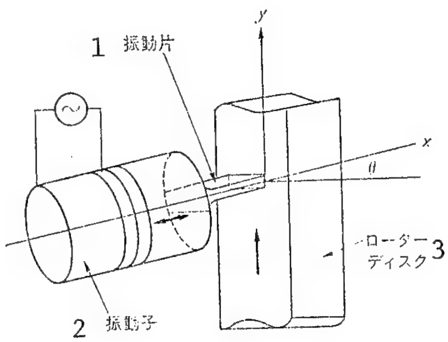

Figure 3. Principle of Ultrasonic Motor

Key:
1. Oscillating piece
2. Oscillator
3. Rotor disc

7. Conclusion

Devices related to microelectronics, optoelectronics, displays, sensors, and mechatronics have been discussed as ceramic solid-state devices. Toward the 21st century; we should expect the appearance of new devices that make active use of ceramics.

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NEW MATERIALS

ELECTROMAGNETIC SHIELD MATERIALS DISCUSSED

Tokyo NIKKO MATERIALS in Japanese Apr 86 pp 89-96

[Article by Masaya Kurata, managing director, Dia Research Institute, Inc.]

[Text] 1. Introduction

Americans complain that Japan acquires technological information from foreign sources but refuses to share its own technological expertise with other countries. However, Americans could not comprehend Japanese technology anyway because it is not written in English. Although we Japanese are dissatisfied with these haughty and arrogant American attitudes, we are working to provide translations because we do not want foreigners to ignore Japan's contributions to human civilization.

The language barrier has several facets. In West Germany, there was an incident involving Japanese students who tried to read Japanese patent documents in Japanese but were not able to acquire them on computer. Japanese public information is controlled by a database system based on the premise that information including Kanji and Kana should be computerized. Personal computers employing such software are of course made in Japan; we Japanese did not think that these personal computers would be used in foreign countries. Unlike personal computers made in other advanced countries, no electromagnetic wave shield is applied to Japanese-made personal computers. Therefore, they cannot be exported to West Germany. As a result, the Japanese patent databases cannot be used in West Germany.

Except in the areas of space and military technologies, Japan is an electronically advanced country. But it is a developing country when it comes to EMI (electromagnetic interference). If an EMI accident had received a lot of publicity from the press, it would have created a great sensation and the government would have become involved in the EMI problem. But up to now the government has stayed out of the problem.

However, optical sensors to count the number of spectators, roller coasters, electric indicating boards, etc., were controlled by computers at the international science exposition Tsukuba '85. Sometimes, this equipment was improperly operated. It is thought that these operations were caused by EMI, because Tsukuba '85 was flooded with computers. Therefore, it has become

impermissible to apply electromagnetic wave shields only to exports. However, the problem of the EMI was recognized late because it is invisible and difficult to diagnose. In any case, this was not related to a value rise of private electronic equipment. But, there are some cases in which defensive measures are taken against outside noise generation. There are some people who have invested in "increased sound quality," an easy decision to understand. But, these people would not invest money in the prevention of EMI, a lesser amount than for noise prevention.

Of course, this is a problem not limited to Japan. EMI is nothing less than environmental pollution caused by the electronic field, which was thought to be a clean industry. Considering EMI as environmental pollution, the reluctance of manufacturers and the uninvolvement of the government can be understood. The government tried to pay attention to the opinions of these manufacturers. In order to prevent EMI, eventually there must be regulations. The United States has regulated EMI since October 1983, while West Germany began to do so prior to that time. In December 1985 the Ministry of Posts and Telecommunications, Telecommunications Technology Council, Electromagnetic Compatibility Committee submitted a draft concerned with the allowable value of jamming and its measuring methods. Jamming is accompanied by the spread of information processing units and electronic office machines. Hopefully, the regulation of EMI will begin in Japan in 1986.

2. Electromagnetic Wave Shield Technology

The concept called "Periodic Binary-Coded Pulse" is included in the definition of information processing units mentioned in the above draft regulating EMI. As mentioned in the draft, EMI is a problem caused by an increase in electronic equipment. No problem existed when using analog circuits employing vacuum tubes at a low frequency. The high frequency pulse includes very high-frequency components. This is one of the causes of EMI. It has become possible to manufacture IC's (integrated circuits) and LSI's (large scale integrated circuits) by using solid state electronic circuits. These IC's and LSI's are widely used because they are compact, lightweight, inexpensive, and possess high performance and high function abilities. Solid state electronic circuits are not resistant to noise.

Another factor which was useful for the spread of the IC's and LSI's is the use of plastics in housing equipment. From the standpoint of strength, steel is used for large computers. But in the case of compact and portable computers, they are assembled in a complex shape, and their assembling processes can be simplified by using an injection molding method. Originally, these compact and portable computers were lightweight. There was no need for insulation and rust prevention. In addition, it was possible to finely color the raw material itself. However, these factors also caused an increase in EMI. Even if the IC's and LSI's high frequency pulses are wrong, if the housing is made of steel, there would not be a problem. Electromagnetic waves interfere all the more because they can pass through plastics. As mentioned above, EMI is an environmental problem. Such problems arise where no preparation technologies exists. Needs have arisen for sheaths but no prior preparations have been made.

Maximum Amount of Allowable Radiation

CISPR			West Germany (VDE)			United States (FCC)			Japan (Plan)		
Frequency	Distance	Critical Value	Frequency	Distance	Critical Value	Frequency	Distance	Critical Value	Frequency	Distance	Critical Value
			0.01~ 30	100	34						
30~ 88	30	30	30 ~ 41	30	54	30~ 86	30	30	30 ~230	30	30
			41 ~ 68	30	29.5						
88~ 230	30	35	68 ~ 174	30	54	86~ 216	30	50			
			174 ~ 230	30	29.5						
230~1000	30	40	230 ~ 470	30	54	216~1000	30	70	230~1000	30	70
			470 ~ 760	10	45.1						
			760 ~1000		59.1 ~59.9						
			0.01~ 30	30							
30~ 88	10	30	30 ~ 470	10		30~ 88	3	100	30~ 230	10	30
88~ 230	10	35				88~ 216	3	150			
230~1000	10	40	470 ~1000	10		216~1000	3	200	230~1000	10	70

Frequency: Megahertz; Distance: m, Critical Value: micro v/m

The first measures against EMI were taken as a stopgap. As mentioned above, EMI problems were caused by a combination of factors. If one of these factors is solved, the EMI problem will be solved. At that time, of course, the problem of plastic housing was taken up as the most nonessential factor for electronic equipment. It is a reasonable claim that when steel boxes were used for computers, the EMI problem did not exist. At present, EMI technology is researching materials. Essentially, this must be recognized as an emergency measure. As will be discussed later, a wiring system has already been considered as a measure against the EMI. The housing problem has already been explained. Of course, the problem of connectors and conductors was reviewed. However, the latter problem was not reviewed in as much depth as the former problem, and was solved with an improvement in the extended wire. Decisive measures for the housing problem have not yet been established.

3. Conventional Electromagnetic Wave Shield Materials

Electromagnetic wave shield materials have been developed over the past several years. The opinion that using steel boxes would cause no problems has changed to the opinion that using metal boxes would cause no problems. Clearly, if computers are stored in metal boxes, these computers will avoid EMI. Many electromagnetic wave shield materials have been devised, developed, and put into practical use. Details are omitted, because these materials have already been adequately discussed in the literature.

The following matter is mentioned while emphasizing the comparison of ideas and recent trends related to the above materials. As previously mentioned, when the electromagnetic wave shield became a problem, it was decided that the housing material would be a stopgap measure. There is a belief now that the circuit wiring system should no longer be changed. In the same vein, not "steel," but the concept "pseudo metal" has been conceived. Namely, the use of plastics has been left as is, and metallic characteristics have been given to electromagentic wave shield materials. The most effective method is to attach metallic foils to these materials. At first, this method was used, but of course, it increased personnel expenses. Recently, other methods have been developed, but it is difficult to give up the benefits of these conductive sheets. This problem is discussed later in the article.

From the standpoint of industrial production, the main method is a zinc spraying process. A thickness of 100 to 150 micrometers is required. Also, measures for preventing peeling and for coping with bad drape in plastics must be considered. In addition, it is necessary to take measures for the working environment. At present, shares are being reduced. The use of a dry plating method such as deposition and the wet plating method such as electrolysis plating and electrolytic plating, will possibly form a metallic layer on the surface of plastic housings. It is said that these have not been industrialized. It would be better to use organic substances, where no problems such as drape pinholes in plastics, etc., exist. A paint spraying method, including fine nickel particles has been developed, has replaced the zinc spraying process, and has become at present a principal method. General-purpose painting facilities meet the requirements. Unlike the zinc spraying process, the painting with 50 micrometers will sufficiently meet the requirements, because the particles of the sprayed paint are laterally linked

with each other. Acheson Japan, Ltd., and Nihon Bee Chemical Co., Ltd., have cornered more than 50 percent of this technology market in the United States. These companies are branching out into the field of electromagnetic wave shield paint. It is said that their share of this market is about 20 percent. Also, Fujikura Kasei Co., Ltd. has obtained actual results of destaticized conductive paint, etc., which requires a conductive level of 10,000 in the field. Shinto Paint Co., Ltd., has introduced technologies from Acme Chemicals & Insulation Division in the United States, and is enthusiastically developing the nonsedimentation of nickel particles. Toshiba Chemical Corp., Stauffer Japan, Ltd., and other companies, are obtaining actual results of such nonsedimentation. The research and development work of the nonsedimentation is continuing. For example, Shinto Paint Co., Ltd., and Toshiba Chemical Corp. have completed research and development on the nonsedimentation of copper and nickel particles. The ensured nonoxidizable conductivity is good. That is, a thinner coat of paint sufficiently meets the requirements. The painting means an additional process after plastic housings have been made. Instead of this process, conductivity concerns should be focused on electromagnetic wave shield materials by carrying out injection molding work. This idea has been conceived. It can be said to be a natural progression, because originally, the plastics industry was developed by reducing the number of sheet metal working processes. (When using steel, raw material cost is half that of metal. The unit price per weight is one-fifth that of metal.)

Many companies listed below have joined the competitive market for conductive fillers and plastic compounds. The companies are: Aron Kasei Co., Ltd., Showa Denko K.K., Dainippon Ink & Chemicals, Inc., Tokyo Printing Ink Manufacturing Co., Ltd., Toyo Ink Manufacturing Co., Ltd., Dainichiseika Color & Chemicals Manufacturing Co., Ltd., Sumitomo Bakelite Co., Ltd., Toshiba Chemical Corp., etc. Regarding conductive paint fillers, the coating and dispersion properties were given top priorities. On the other hand, there was no concern about strength when applying paint to the finished moldings. These fillers were made of particles. However, in the case of the molding filler, strength must be ensured. Unlike glass fibers, etc., the molding filler is a metal which cannot be called "Reinforced Composite Material Element" or the like. Therefore, emphasis is laid on reducing the inclusion rate as much as possible and sufficiently enhancing conductivity. (If the degree of drape with plastics is enhanced by treating the metallic surface, then reinforced fibers will be obtained. But, this cannot guarantee the continuity. It is absolutely necessary that metallic raw materials have direct contact with each other.) Fibers or flakes must be used in fillers, because it is impossible to use powder. There are various companies specializing in flake, fiber, and both. Nickel-plated glass fiber, nickel-plated carbon fiber, etc., can be cited as fibers, but a matter deserving special mention is "vibration cutting metallic fiber." The self-oscillation of cutting tools is a harmful phenomenon, but metallic short fibers with a specified shape and size can be manufactured by making the best use of this harmful phenomenon. The term, "Conversion of Conception" is an explanation in applying for a patent. This technology was invented in Japan, and was a sheath developed in reply to the suddenly generated needs for electromagnetic wave shields. Several companies

such as Aisin Seiki Co., Ltd., are cultivating a market for the technology under license. There has not been a large demand for conductive fillers and plastic compounds as yet.

First of all, the cost is really high. Taking the ABS (acrylonitrile butadiene styrene) resin as an example, with a unit price of about Y450 per kilogram, it is estimated that the electromagnetic wave shields will be Y2,000 per kilogram. The expense of plastic materials has been justified by the fact that the number of processes is less than that of sheet metal working. But, this estimated price is excessively high. In addition, a necessary aspect is not weight, but volume. The specific gravity will be raised, and the necessary weight will be raised in accordance with the increased specific gravity because a conductive metal is used. But, the comparison of cost lies in paint, as long as electromagnetic wave shields are required. Generally speaking, this is also expensive. Although it has been decided that insulation painting is required for conductive resin compounds, the UL standard stipulated in the United States has not yet spread throughout Japan. This is a serious problem for the "painting" competition. Regarding conductive painting, it is necessary to uniformly paint ribs up to their right-angled corners. The painting process using conductive paint is the same as that of external painting of simple-curved surfaces, but the former has a higher degree of difficulty than the latter. Also, it seems that the color of the resin with conductive fillers is undesirable.

However, there is no doubt that the target, "injection molding work" will be given away. Eventually, the masking and demasking work accompanied by the painting and metal plating processes will be carried out. It can be said that this is reasonable. Considerable know-how is required to uniformly disperse the fiber and flake while maintaining mutual contact between fillers, in other words, while ensuring conductivity. Assuming that a surface layer exists in only the resin, the resin temperature and injection speed must be enhanced so as not to expose the metal. However, would it be possible to uniformly disperse fillers up to the weld line which meets two streams under the same condition? Assuming that the resin processing work is carried out even in small town factories, conductive fillers which can cause an electric shock may appear on the surface layer. This aspect in UL's philosophy is understandable.

4. Recent Tendency

A matter deserving special mention in conductive resin compounds has been studied by Aron Kasei Co., Ltd. The company has long directed its attention to an aluminum flake invented by Battelle Memorial Institute in the United States and has made a system with an optimum ABS resin in collaboration with Japan Synthetic Rubber Co., Ltd. However, Aron Kasei Co., Ltd. has found the single-compound system resin limit, and has increased the research and development of a laminate system resin. The appearance of the laminate system resin is the same as that of a normal resin, with conductive fillers being put inside of the resin. The company has also completed an injection molding machine in collaboration with the Japan Steel Works, Ltd. With regard to the sales of injection molding machines, it seems that a business tie-up with Mitsui & Co., Ltd., has recently begun along these lines. If this method

employed by Aron Kasei Co., Ltd., is used, the injection molding work can be carried out by developing plastic insulation with a freedom of clear colors. The is a sandwich type laminate system based on the Battenfeld method developed in West Germany. This type is inferior to the method employed by Aron Kasei Co., Ltd., because in many cases, when housings are assembled, a shield will not be effective unless these housings are electrically connected with each other, and a conductive layer will not be exposed unless peeling is further promoted. Would it not be difficult to connect the earth wire to a good ground, even if housings are not assembled?

Aron Kasei Co., Ltd. is actively cultivating a market for laminate system resins. An undesirable aspect of the company is to compel users to invest in injection molding machines. Therefore, the company will probably carry out the molding work on consignment. This molding work is not injection molding work, but press work. Also, a two-layer laminate material has been developed. Recently, Denki Kagaku Kogyo K.K. has announced a two-layer laminate material base on polystyrene. It seems that new entries into the paint market were set, but recently, Dai Nippon Toryo Co., Ltd. put an in-mold electrostatic viscous paint product on the market. This step by the company should be analyzed as an action taken with full knowledge of the resin. Materials based on iron are enthusiastically being developed. This is noteworthy as a recent tendency which is completely different from a past tendency for painting and molding resins. As mentioned above, when materials are used for electromagnetic wave shields, wiring considerations will be taken. This is a measure taken to protect against a low-frequency magnetic field. Aluminum, copper, etc., completely pass the low-frequency magnetic field. Although materials such as aluminum, copper, etc., reject magnetic field waves generated from a long distance, they put out those generated at a short distance. Therefore, attention is turned to a current loop which is a magnetic field, without any reliance on these materials, and it is devised so that other magnetic fields interfere with each other.

But, if materials complete continua with high magnetic permeability and a measure of thickness, they will accept magnetic fields and will not put them out. Iron continua are such materials. Toppan Printing Co., Ltd. and Showa Laminate Printing Co., Ltd. use pure iron foils based on an electrolytic process. Toppan Printing Co., Ltd. may use other metal foils. Bando Chemical Industries, Ltd., uses galvanized sheets. Showa Laminate Printing Co., Ltd. has responded to a call from Toyo Kohan Co., Ltd., by manufacturing iron foils, and will market them in the United States. These iron foils have the previously mentioned advantage of being composite materials. However, the molding freedom lies in the depth to which the iron foils can be drawn. Kanebo Synthetic Fibers, Ltd. has reported very unique results by using iron fibers. Unlike aluminum, etc., iron fibers are hard to break. The efficiency of iron is higher than that of aluminum, expected from respective resistivity values of iron and aluminum. In addition, the iron fibers have the mechanophysical property of reinforced fibers due to a chemical activity on the surface. It can be said that this aspect is exceedingly important in the case of nylon. The biggest merit is as follows: The shield effect at a low frequency region is equivalent to that of iron plates when using more than 20 percent volume. Kanebo Synthetic Fibers, Ltd. has dealt with various fibers, and has recently developed the above. Recently, topics dealing with fiber

have been increased, particularly, metallic plating based on inorganic and organic (synthetic) fibers. Metallic plating based on glass fiber has been carried out by Asahi Fiber Glass Co., Ltd., Nippon Sheet Glass Co., Ltd., and Nitto Boseki Co., Ltd.; that based on carbon fiber has been carried out by Toho Rayon Co., Ltd.; that based on polyester, etc., has been carried out by Takase Dyeing & Printing Works, Ltd., Seires Co., Ltd., and Urase Godo Senko K.K.; that based on aramid fiber has been carried out by Teijin, Ltd. The aramid fiber has high heat resistance.

5. Conclusion

It seems that if domestic regulations are executed, the paint market will be expanded, and the injection molding of small parts will be promoted. After that, what would become of the market? For reference purposes, painting advocates of electromagentic wave shields say that it is possible to divert existing facilities to some other purpose.

Material manufacturers should know that methods for preventing environmental pollution have been developed successively and technologies for eradicating problems have been enhanced. They should remember and refer to this fact in their planning.

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SCIENCE AND TECHNOLOGY POLICY

PROGRESS OF KEY TECHNOLOGY CENTER DISCUSSED

Tokyo KOGYO GIJUTSU in Japanese Aug 86 pp 20-32

[Text] Part 1. Roundtable Discussion

(Nakada) Let us begin our roundtable discussion. First, I will ask Director Hongo to explain the funding situation at the Center.

(Hongo) The main purpose of the Key Technology [Promotion] Center is to supply necessary funds for testing and research in key technologies in the private sector, based on the "key technology promotion law." Launched in October of last year, it invited project participation by private enterprise in January of this year, and the projects were selected at the end of March. Today, a civilian joint research and development company has been established to carry out the projects, and it is in the initial stage of operations.

A total of 28 research and development projects were submitted, from which 17 projects were accepted. Classified by fields, the breakdown includes: 5 items related to electronics, 2 items each to new basic materials and biosciences, 7 items to communications and 1 other item. Today, with the 17 projects actually having made a start, we would like to discuss with two among you, who have been involved in research in industrial and academic circles, or have been leaders in the technology sector, about the Center--focusing on the role expected of it in Japan's present research and development. We would also like to hear any requests or advice from you that may be of use to the work at the Center.

(1) Importance of Basic Research and Need for Its Buildup

(Nakada) First of all, I would like to have you discuss the importance of basic research as a backdrop for the establishment of the Center, and the need for its buildup.

(Tanaka) Regarding research in Japan in the past--particularly research in engineering and technology--there was undeniably a trend since the Meiji Era to follow in the footsteps of Europe and America. Even today, there is the undeniable fact that much more emphasis is placed on application than the basics.

I once read about an opinion poll conducted by the Ministry of International Trade and Industry [MITI] showing that only 0.8 percent believed Japan is superior to Europe and America, while 86.8 percent believed that Japan is inferior.

It is also clear from the number of Nobel prize winners that very little epochal and revolutionary technology and research is seen in Japan.

Fortunately, major projects have been launched by the MITI since 1966. Also, research and development in key technology for next-generation industries began in the late 1970's, and the Key Technology Center was launched recently. I think it is wonderful that the government is providing major assistance to private research.

(Nakahara) In postwar Japan, the living standard was extremely low at the outset. Subsequently, we entered the so-called "high growth era." Everyone worked feverishly, the per capita GNP rose and the living standard improved remarkably.

However, around the late 1970's, major disruptions hampered the improvement of our living standard and economic growth. One was the oil crisis, which greatly altered the pattern of our economic growth.

Another was, I believe, around 1983 when Japan's GNP surpassed 10 percent of the global GNP, and its trade surplus rose above $20 billion, resulting in fierce trade frictions. Trade frictions are presently thought to be the major factor that obstructs Japan's economic growth.

In 1984, the 11th report [to the prime minister] was drafted by the Council for Science and Technology regarding promotional measures for science and technology from the standpoint of a long-range response to such changes in the situation. One fundamental line of thinking was that greater emphasis on basic research with abundant creativity was indispensable for the easing of international friction. Another was that past development in Japan did not necessarily involve adequate consideration toward human beings, and that it was necessary to exert greater efforts toward "harmony between science and technology and the human society." Also, the conclusion was that, since Japan's research and development spending was equal to only about 2.5 percent of its GNP and was much lower than in the countries of Europe and America, it was necessary to raise it to between 3-3.5 percent as soon as possible.

From the viewpoint of the industrial circles, one effect is to be able to refute the accusation that Japan is not contributing adequately to the international society because it fails to conduct basic research. Also, in Europe and America, there is a recent movement to place greater emphasis on intellectual proprietary rights and to curb the advance of "catch-up" nations and enterprises. Therefore, basic research can be extremely crucial as a countermeasure.

In the past, applied research and development research were conducted for major projects. However, this was found to be inadequate, and key technology

for next-generation industries was started at the stage of target-oriented basic research. Nonetheless, it can probably be still considered as inadequate.

It is a problem that stems from the fact that three-fourths of Japan's research and development is in the private sector.

From this standpoint, the salient point of the current funding system at the Key Technology Center is that it is a new system whose targeted basic research is planned with the initiative of private enterprise, which carries a large weight in its funding, while the government performs an assisting role. I believe this indicates that it [the Center] is highly evaluated as a step in the growth (of research and development) from 2.5 percent to 3 percent.

(2) Emphasis on Basic Research and the Utilization of Private Vitality

(Hongo) A little while ago, Professor Tanaka stated concerning testing and research in Japan that greater efforts are directed toward application than on basic research, and more effort toward development than on applied research. It is only a natural direction to be expected of private research.

Meanwhile, the Key Technology Center is structured with two objectives: to stress basic research, as well as the power of private enterprise and the solicitation of the full use of that power. The trend in the past has been to combine the two opposing factors and to thus seek a new direction. Therefore, I believe there is an extremely delicate balance between the two objectives, and that a very difficult task is involved here.

(Nakahara) I have two opinions regarding this point. One is my doubt regarding the thinking that there is basic research and there is target-oriented basic research, and then there is applied research and development, and then manufacture and sales.

In other words, industry actually depends on a great many feedbacks, and the flow is not that simple. On this point, I think that, despite the failure of Japan to be involved very much in basic research, it has been highly successful as far as industry is concerned. In other words, the private sector has actually had the capability for basic research that has aided its growth. Based on this understanding, I believe that it is an extremely good thing to direct the private sector toward basic research, as we are doing.

My other opinion concerns the fact that, last year, experts in the high tech fields from Japan and the United States held a series of discussions and collected data on the differences between our two countries. The data indicated that, in America, basic research is conducted actively by the universities. In Japan, however, the weight lies surprisingly heavier toward the private sector. Moreover, if we look at the annual trend, the rate of private basic research (in Japan) is rising. Based on this fact, I believe that active participation by the private sector in basic research is a very good thing for Japan.

(Tanaka) I agree fully with what Mr Nakahara has just said. I think that the Japanese private sector did not have such a great potential for basic research immediately after the war [World War II], but only since the late 1960's.

I believe this is particularly true with respect to electronics. I myself know quite a bit about steel, so I would like to use it as an example. I feel quite strongly that there is a wealth of talent in the research sector of Japan's steel companies, and that they have a well-balanced potential in fields ranging from the basics to application. I believe that it is a major reason why Japan's steel industry has reached the world's highest level.

I believe it is very important that the technological standard became balanced with the surrounding scientific standards, resulting in higher levels. I feel that, during the past 20 years or so, Japan has done quite well in this respect.

(Nakahara) Basic research has an extremely large potential. If we think of what technologies will make great strides...probably new basic materials, bio materials and others like them, for example, have the greatest potential.

I think that, in the future, greater weight should be given to materials and the bio sciences, for example.

(Hongo) Previously, when the 17 projects were decided, the same problems between the different fields just referred to by Mr Nakahara were pointed out. As we conduct operations at the Center, I think that we must adequately consider such problems of direction.

(3) Characteristics of the Center's Funding System

(Nakada) I would like next to hear your views on the characteristics of the Center's funding system.

(Hongo) There are many opinions on this point. One is the view that the handling of the results is characteristic. Since previous large-scale projects and key technology for next-generation industries are consigned research, the results belong to the state. However, in the current system, the results belong to the testing and research firms--that is, to the private sector, and this is probably a major difference from the previous system.

Also, there is the view that easing of controls is characteristic. Since major projects and next-generation projects are state projects, the state has firm control over research. However, since the current system is a private project, the Center provides support for funding without state control over research, and the view is that the free exercise of talent is made possible through private initiative.

(Nakahara) In private enterprise, management responsibility to continue company operations exists at the base. Since a general stockholders meeting is held annually, unless appropriate profits can be reported at the meeting,

it will be impossible to continue company operations. Consequently, basic research will naturally be limited.

In such a situation, the fact that the Center provides 70 percent of the funds is a major incentive.

Another point is that recent basic research has become large-scale, and in this age a considerable amount of funds and large personnel must be expended for a lengthy period if anything really new is contemplated. In this sense, I believe that the availability of the merits of joint research becomes a great incentive.

(Tanaka) I believe the greatest merit of the current system lies in the fact that funds will be provided without vocal interference.

(4) Possibility of Industry-Academia-Government Cooperation

(Hongo) It has been common knowledge that basic research is inherently conducted in the universities. From this standpoint, how do you see the Center's funding projects?

Whereas the universities conduct extremely specialized research, I believe that the Center conducts many interdisciplinary projects that combine various areas of specialization.

(Tanaka) There is much discussion everywhere about cooperation between the industry, the academia and the government agencies. However, the problem is that funds do not flow to the universities due to money barriers between the various government agencies.

Regarding research at the Key Technology Center also, although actually no funds come to the universities ostensibly, I believe that cooperation with the universities will bring very beneficial results. I am all for the use of our universities, and am hopeful that it will result in a smooth flow of funds.

(Hongo) Among the current funded items are several projects for which research laboratory directors of the universities and principal researchers will be coming to the Center. Also, there were conspicuous restrictions previously with respect to cooperation with national laboratories, but those restrictions will be eliminated under the "research exchange promotion law" passed this spring. The surrounding changes have thus improved conditions, so that there will be several projects with participation by people from the national labs. Therefore, I believe that the Center will become one of the places for joint projects where the dividing walls between the universities, the national labs and the private sector will be removed.

(5) Advice Concerning the Center's Funding System

(Nakada) Finally, I would like to hear any requests or advice you may have concerning the future projects at the Center.

(Nakahara) Basically, I think it is a very good system. However, since it is starting out with a new system, I believe that, once you start out, there will be many things that will need complementing. First, there is the problem of handling corporate funds vis-a-vis the research and development firms. In particular, there is spending for testing and research, of course, due to the nature of the firms. The major problem is that writeoffs of losses incurred in testing and research spending are impossible. Also, problems after the completion of research and development are: evaluation of the results and the method of returns. On these points, I hope that company-based views will be taken into consideration.

Furthermore, how will the company projects be managed? How will difficult and advanced research be evaluated, and how will checks and reviews be conducted? These are problems that will prove to be difficult if hard-and-fast rules of the past are adhered to. In other words, I believe that considerable flexibility is necessary for smooth management.

(Tanaka) I think it is extremely important that interim increases are made in necessary funds for research. In particular, I believe that a certain amount of cutbacks are made at the screening stage. I believe that cutbacks should be avoided as much as possible, and that checks and reviews should be strictly implemented instead. Any project that fails to show progress should be cut in midstream, so that the funds can be used more effectively.

(Hongo) Since the key to the current system lies in supporting private ingenuity, we will bear in mind what you have discussed here today, and will do our best to make use of them.

Part 2. Present Status

--By the Key Technology Research and Development Promotion Office, General Affairs Section, Agency of Industrial Science and Technology

The Key Technology Center, which was established in October of last year, entered its second fiscal year of operations, and has commenced full-fledged activity.

This is a report on the present status of the Key Technology Center's manifold operations.

Chapter 1. Introduction of the Key Technology Center

Technological development is important from various standpoints, such as accelerated advancement of the industrial structure and the employment structure, contribution to active international trade, contribution to qualitative upgrading of the people's livelihood and economic security. Its importance will continue to rise as we head into the 21st century.

In Japan, with its numerous limiting conditions in terms of resources and land, aggressive promotion of technological development is indispensable in order to overcome these limitations and to secure the nation's continuous growth base, as well as to contribute to the international economic society.

In the past, Japan tended to fall behind the countries of Europe and America in grappling with technological development in the application stage. However, in order to cultivate its creative technological capability and to further upgrade its industrial activity and national livelihood, it is important to apply drastic efforts toward technological development in the stages of basic and applied research in areas of key technology, where the ripple effects are also large.

The state naturally plays a major role in the promotion of technological development. At the same time, if we consider the fact that private enterprise is funding about 70 percent of all research and development spending in Japan, it is the pressing task of private enterprise to maintain environmental conditions enabling the maximum use of its vitality for key technology development.

Recognizing the importance of this new policy, a joint conference of the planning subcommittee of the Industrial Council's general subdivision and the planning subcommittee of the Industrial Technology Council's general subdivision established a core organization, on 27 November, that will integrate and effectively implement the private maintenance of environmental conditions to promote industrial technology development. The joint conference drafted a report proposing a reexamination of the current systems that limit technological development in the private sector. It also proposed the enactment of a new law pertaining to industrial technology development, including improvements.

On the basis of this report, the MITI [Ministry of International Trade and Industry] deemed that the establishment of a specially authorized corporate industrial technology center was indispensable. The center was to be established under private volition and operated under private ingenuity as a nucleus organization to integrate the supply of risk monies, to promote joint research with the purpose of strengthening cooperation between the industry, the academia and the government agencies, to promote international cooperation in research, and to carry out projects on the dissemination and promotion of research data. The MITI has accordingly contacted the various related sectors.

Meanwhile, the MPT [Ministry of Posts and Telecommunications] has been working on a concept for the establishment of a special corporate telecommunications promotion organization to promote telecommunications. In December 1984, during the budget drafting process, it was decided to combine the two concepts and to establish a new specially authorized corporate key technology [research promotion] center. It was thus decided to establish the center and to finance it with 10 billion yen from the government's industrial investment special account and 3 billion yen from the Japan Development Bank that would be included in the government's FY85 budget draft.

In view of these events, and based on the "key technology research facilitation law" (enacted at the 102d Diet session, and publicly announced and effected on 15 June 1985), whose main content includes the establishment of the Key Technology Center, low-cost use of national testing and research

facilities, and an easing of controls such as a more flexible treatment of patents in international research cooperation, the Key Technology Center was duly established under special authorization on 1 October 1985.

The principal operations of the Key Technology Center are as follow.

1) The Center will provide funding for technology development projects implemented by two or more enterprises, beginning from either the basic research stage or the applied research stage.

2) Loan Projects

The Center will help to mitigate risks and capital burdens attending technology development by private enterprise through conditional non-interest loans.

3) Facilitation of Joint Research

The Center will provide assistance for testing and research by private enterprise concerning key technology conducted jointly with state [national] testing and research organizations.

4) Consignment Research

The Center will accept consignments from private enterprise and mobilize knowledge from the industry, the academia and government agencies in conducting testing and research.

5) Japan Trust Project for International Research Cooperation

The Center will use public benefit trust funds to implement the Japan Trust Project for International Research Cooperation, and invite outstanding researchers from abroad.

6) Research Data Service

The Center will widely collect valuable research data held by state research institutions, and will offer it to researchers engaged in key technology research and development, after editing and arranging the data in a form immediately useful to research activity.

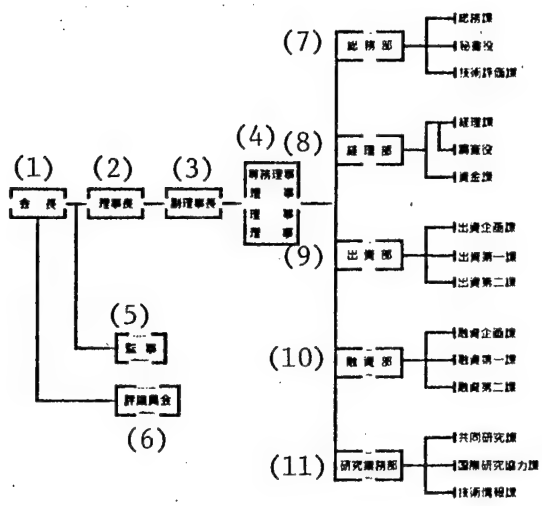
7) Surveys

The Center will conduct a variety of surveys for the promotion of testing and research concerning key technology in the private sector.

8) Incidental Projects

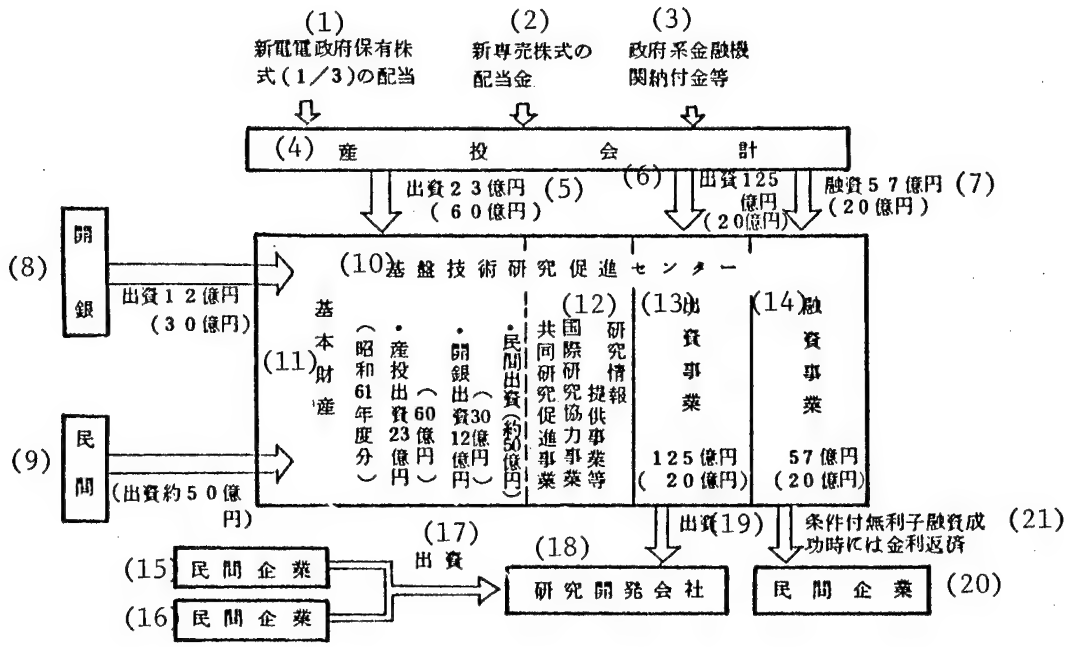
The Center will conduct affairs incidental to items 1) to 7).

The present status of the aforementioned Center affairs will be explained in Chapter 2 and thereafter.



Organization of the Key Technology Center

Key:
1. Chairman
2. Chief director
3. Assistant director
4. Executive director
   Director
   Director
   Director
5. Inspector
6. Board of Trustees
7. General affairs department
   - General affairs section
   - Secretary
   - Technology evaluation section
8. Accounting department
   - Accounting section
   - Investigator
   - Funds section
9. Funding department
   - Funds planning section
   - 1st funding section
   - 2d funding section
10. Loan department
    - Loan planning section
    - 1st loan section
    - 2d loan section
11. Research affairs department
    - Joint research section
    - International research cooperation section
    - Technology data section



Key Technology Center-Related Funds Flow
Figures in ( ) indicate FY85 funds

Key:

1. Dividend (1/3) of new Telegraph and Telephone Corporation stocks held by the government
2. Dividend of the new (Tobacco) Monopoly Corporation
3. Subsidies by government-related loan institutions
4. Industrial investment account
5. Investment: 2.3 billion yen (6 billion yen)
6. Investment: 12.5 billion yen (2 billion yen)
7. Loans: 5.7 billion yen (2 billion yen)
8. Development Bank of Japan
   Investment: 1.2 billion yen (3 billion yen)
9. Private sector
   (Investment: about 5 billion yen)
10. Key Technology Center
11. Basic assets
    Industrial investment account funds: 2.3 billion yen (FY86 funds)
    Japan Development Bank funds: 1.2 billion yen (6 billion yen)
    Private funds: about 5 billion yen (3 billion yen)
12. Joint research promotion projects
    International research cooperation projects
    Research data servicing projects
13. Funding projects
    12.5 billion yen (2 billion yen)
14. Loan projects
    5.7 billion yen (2 billion yen)
15. Private enterprise

[Key continued on following page]

16. Private enterprise
17. Funding
18. Research and development firms
19. Funding
20. Private enterprise
21. Repayment of interest when conditional non-interest loans are approved

The Key Technology Center is organized as shown above in order to carry out its operations smoothly.

In May of this year, the Center moved to its newly completed Arc-Mori Building in Akasaka, Minato Ward [Tokyo], and began full-fledged operations.

Chapter 2. Investment Projects

The purpose of this system is to supply necessary funds for testing and research on key technology in the private sector. Funds are provided for the appropriate corporate enterprise that meets one of the following conditions.

1) A corporation that is established with funding by two or more enterprises for the purpose of conducting testing and research on key technology, beginning from the basic research stage or the applied research stage.

2) A corporation that is established with funding by two or more enterprises for the purpose of conducting testing and research for the promotion of the "teletopia" concept or the new media community concept, in addition to purposes mentioned in Category 1).

3) A corporation that meets conditions in Category 1) will be provided with funds for a period within 7 years in principle, with a limit of 70 percent of the funds necessary for testing and research.

4) A corporation that meets conditions in Category 2) will be provided with funds for a period within 5 years, with a limit of 50 percent of funds necessary for testing and research.

As an FY85 funding project, the public was invited to submit loan requests between 10 and 24 January 1986, which resulted in 36 funding requests. After careful screening, 25 items (total funding for FY85: 2 billion yen) were selected at the end of March. The breakdown of the 25 items was: 10 items in the mining industry that qualify under Category 1), 7 items in telecommunications that qualify under Category 1), 1 item in the mining industry that qualifies under Category 2) and 7 items in telecommunications that qualify under Category 2).

A look at the projects selected in the mining industry shows a good balance between such advanced areas as electronics, new basic materials and bio sciences. Simply stated, the contents are as follow. (Company names in brackets are newly established companies.)

i) Research and development of nonoxide glass (Nonoxide Glass Research and Development, Ltd.)

Heavy element chalcogenide glass, such as selenium and tellurium, will be developed as materials for glass that will transmit light with a 10-15 μm long wavelength zone (infrared ray), or that has optical functions. It is expected that it will drastically increase the use of infrared rays in the fields of medical care (laser scalpel) and remote sensing, and also increase the use for optical memory.

ii) Research and development of the second-generation optic-electronic integrated circuit (Optic Electronic Research and Development, Ltd.)

The optic-electronic integrated circuit [OEIC] is an integrated circuit with an optical element and an electronic circuit mounted simultaneously on a single crystal plate. At present, a transmission speed of 1G bit/S has been realized. However, process techniques and device techniques will be developed, with an increase to 10G bit/S as the goal.

iii) Integrated research on the use of the space environment (Space Environment Use Research Laboratory, Ltd.)

Through experiments in space, efforts will be made to establish innovative material-processing technology in fields like electronics that utilize the microgravity environment in space. In addition, necessary space test equipment will be developed.

iv) Research on measurement basic technology for use in coherent optical communications (Optical Measurement Technology Development, Ltd.)

In view of the trend toward large-capacity optical communications, a signal mode to change the number of vibrations of light is being contemplated as a replacement for signals based on the strength (and weakness) of light. For this purpose, a light medium with a heightened wave coherence is necessary. The goal is the practical application of optical measurement technology to measure light loss, light power, frequencies and phases in response to such coherent light.

v) Research on the establishment of a manufacturing method for active peptide through gene manipulation and chemical synthesis, in addition to research on the development of an active screening method (M D Research, Ltd.)

In order to eliminate structural differences between natural peptides that could not be overcome by previous gene manipulation methods and chemical synthesis, and to produce peptides with similar vitality as natural products, a method of chemical analysis through a liquid phase method and a unique enzyme that will selectively slice peptides will be developed.

vi) Protein engineering (Protein Engineering Laboratory, Ltd.)

Regarding proteins that control the functions of living organisms, an explanation of the relationship between their structures and functions will be sought. In addition, the artificial design and creation of more purpose-oriented proteins and protein-model substances, together with their industrial uses, will be attempted.

vii) Research on an advanced data-processing type of image-data system (Key Data System Development, Ltd.)

In order to establish a completely new system with integrated functions that process and provide image, voice and data information, necessary system design methods, data-processing techniques and key equipment will be developed. In addition, evaluation and research will be conducted to build and operate a testing system, as well as research concerning its functions and capabilities.

viii) Research and development of synchrotron radial ray use technology (Sol Tech, Ltd.)

If a substance is exposed to light, changes occur in its chemical unity and structure. This reaction is conspicuous in the wavelength spheres ranging from the vacuuous infrared sphere to the soft X-ray sphere. Synchrotron radial light is a parallel light source in this wavelength sphere that is twice as powerful as other light sources. Integrated industrial technology will be developed by using this in a variety of fields, such as superminute processing and photochemical reactions.

ix) Development of a metal material with a high-capability surface (Limes, Ltd. [phonetic])

By greatly upgrading and combining various surface processing techniques, such as physical vaporization and chemical vaporization, efforts will be made to form a variety of materials with such functions as erosion resistance, heat resistance and abrasion resistance on the surfaces of existing materials, as well as efforts to enhance their functions.

x) An electronic dictionary for natural language processing (Japan Electronic Dictionary Laboratory, Ltd.)

This dictionary will be necessary for a computer to recognize language ordinarily used by human beings (natural language processing). A prototype will be made of a large-scale electronic dictionary with broad contents. For this purpose, it will be necessary to comprehensively and systematically arrange a huge volume of language data in machine-readable form.

xi) Development of a data system for a wholesaler complex (Takasaki Data Service, Ltd.)

Research will be conducted on office processing characteristic of the wholesale business in a wholesaler complex, and on unified business protocol for incoming and outgoing transaction orders. In addition, technology will be developed for the joining of various terminal equipment owned by the wholesalers and software for an outline system of office processing and the sending and receiving of orders, with such equipment as a premise.

In addition to the above-mentioned projects, the following projects have been approved.

--Human scientific research of a visual-aural mechanism (ATR Visual Aural Laboratory, Ltd.)

--Basic studies of an automatic translation telephone (ATR Automatic Translation Telephone Laboratory, Ltd.)

--Basic studies on an intelligent communications system (ATR Communications System Laboratory, Ltd.)

--Basic studies on photoelectric wave communications (ATR Photoelectric Wave Communications Laboratory, Ltd.)

--Development of an intrabuilding integrated data communications system (Future Building Research and Development, Ltd.)

--Development of an association-type data storage and communications system that will make possible audio input and output, using a personal computer (Japan Database Network Laboratory, Ltd.)

--Research and development of key technology for the construction of a joint backup communications network (Call Net, Ltd.)

--Testing and research concerning the Kumamoto data guidance system (Kumamoto Videotex Service, Ltd.)

--Testing and research concerning a regional data system to revitalize the home community (Matsue Data Center, Ltd.)

--Testing and research concerning an integrated data system for the Suwo Wide Area Teletopia (Suwo Wide Area Data Center, Ltd.)

--Testing and research concerning the Yamaguchi Triangle Information Regional Data Communications System (Yamaguchi New Media Center, Ltd.)

--Testing and research concerning the INF Integrated Data System (Information Network Fukushima, Ltd.)

--Testing and research concerning technology for use by the Kurume Teletopia Regional Data Communications System (Kurume-Tosu Wide Area Data, Ltd.)

--Testing and research concerning the Kagoshima Videotex System (Captain Kagoshima, Ltd.)

As funding for FY86, public bids were accepted between 23 June and 7 July 1986. (Total funding expected in FY86: 12.5 billion yen, including continuing funds.)

Chapter 3. Loan Projects

This system reduces interest burdens resulting from failures in testing and research by providing conditional non-interest loans, in addition to reducing risks and capital burdens attending technological development by private enterprise.

The system is targeted to start mainly from the applied research stage for testing and research in key technologies.

The loan conditions for the system are as follow.

1) Loan Object Costs

Facilities and equipment costs, materials costs, commodities costs, labor costs, outside orders costs and miscellaneous costs.

2) Limitations on Loans

Seventy percent of loan object costs.

3) Terms of Redemption

Within 10 years after the end of the deferment period.

4) Repayment Method

As a rule, repayment to be in two installments per year

5) Deferment Period

The period until the end of testing and research (within 5 years, in principle).

6) Loan Interest

No interest is charged during the deferment period.

In order to calculate the rate of interest for the loan period following the deferment period, the interest rate determined at the time of the loan (6.05 percent per year, as of August 1986) is multiplied by 1.0, 0.75, 0.5, 0.25 or 0, depending on the degree of success in pertinent testing and research.

Also, the degree of success is determined at the end of the testing and research period.

7) Rewards for Success

Based on the interest rate calculated on the basis of the degree of success under item 6), a sum equivalent to the interest during the deferment period, calculated at simple annual interest, is paid in installments at the time of redemption of the principal.

As a loan project for FY85, public subscription was conducted between 10 and 24 January 1986, and 95 requests for loans were received. As the result of strict screening, 60 items (total loans in FY85: 2 billion yen) were accepted. (See chart below)

As a loan project for FY86, public subscription was conducted between 23 June and 7 July 1986. Total loans expected in FY86: 5.7 billion yen (including continuing loans).

Accepted Number of Items by Categories

Category	Accepted number of items
New basic materials	10
Bio sciences	6
Machinery	5
Electronics	13
Radio and satellite communications	10
Transmission	7
Image communications	3
Networks and others	6
Total	60

Chapter 4. Facilitating Joint Research and Consignment Research Projects

In order to strengthen and upgrade cooperation between the government and the private sector, and thereby promote testing and research in key technology in the private sector, joint testing and research will be facilitated concerning key technology between nongovernment and government research organizations [hereafter referred to as "joint research"]. In providing such facilitation, the Center will strive to grasp the needs attending joint research between nongovernment and government testing and research organizations, in addition to their technical, human and capital research potentials. The obtained data will be offered to both government and private sectors on a need basis, and business affairs relative to the content of matching themes will be implemented.

In order to search for prospective themes for joint research facilitation and to review items to be considered for joint research facilitation (joint research environment surveys), a hearing was held in FY85 with some national

testing and research institutions. At the hearing, problems peculiar to the various institutions, as well as general problems concerning joint research and the structure of the institutions, were reviewed. Also, a questionnaire was conducted among 400 companies from the first-section and second-section stock companies listed with the Tokyo Stock Exchange, who have responsible officers in their technology sector (research and development sector), and 100 unlisted research and development companies (with more than 200 employees each). The questions were concerned with the actual status of past joint research among private enterprises, the conditions considered necessary by enterprises without any past experience in joint research in case of future joint research, and requests regarding the "facilitation of joint research projects" by the Center.

Furthermore, for the purpose of reviewing the smooth progress of joint research facilitation projects, key items pertaining to joint research and its facilitation were pointed out, including the establishment of a "joint research promotion committee," and the search for problems attending joint research. Among them, the importance of individuals with special skills that serve as the core in integrating joint research was clarified.

In FY86, as mentioned before, it is planned to dig up prospective tasks, to compile pamphlets containing consignment research projects, and to conduct activities to spread the knowledge among private enterprise. Also, in the latter half of the year, among the research projects proposed during the search for prospective themes, those considered appropriate for consignment by the Center will be selected. A review is in progress to form an outline research plan concerning such tasks.

Chapter 5. Data Service Projects

(1) Foreword

Data is of increasing importance in promoting research and development. In order to conduct research and development effectively amid the high advance of technology and its interdisciplinary and interindustrial expansion, it is desirable for information and data necessary for the research process [hereafter referred to as "science and technology information"] to be properly and immediately obtained.

Meanwhile, with the rapid progress of computers and communications as a backdrop, the database of science and technology information has advanced, online reference has become possible, and online service is being provided by the Japan Online Information System [JOIS] of the Japan Information Center for Science and Technology [JICST] and the Patent Online Information System [PATOLIS] of the Japan Patent Information Organization [JAPIO]. Information required by researchers is now easily obtained through the use of such systems. The value of gathered, arranged and databased information has increased drastically, and the use of science and technology information through online reference has become increasingly important.

However, such presently distributed databases consist mainly of bibliographical information by collecting, arranging and databasing documented information. From the standpoint of directly seeking effective research through laboratory automation, it is still inadequate.

It is desirable for further effective research to database fact information (raw information, such as numerical data), and to maintain and upgrade the online service system.

(2) Present Status of the Fact Database

Databasing of fact information in Japan, other than natural observation data (meteorological information), is generally on a small scale, and service to the general public is virtually nonexistent. Japan is admittedly lagging far behind Europe and America.

Advanced measurement technology is indispensable for the databasing of fact information, and evaluation technology for data is also demanded. The buildup of a fact database for this purpose is being promoted, centering on testing and research institutions in the universities and government agencies, where technology and knowledge is concentrated. However, practically all of them are limited to internal use. In order to promote research in such advanced technologies as electronics, new basic materials and bio sciences and key technological fields, the buildup and maintenance of a fact database for science and technology is necessary. It is also desirable for such a fact database to be offered broadly to the public.

(3) Information Service Project at the Key Technology Center

In order to promote research on key technology in the private sector, it is the Center's policy to provide fact data consisting of numerical data and diagrams, in addition to fact information such as images that are stored at 17 research institutions under the umbrella of the AIST [Agency for Industrial Science and Technology] and the MPT [Ministry of Posts and Telecommunications], where leading technological development is promoted in the fields of mining and telecommunications.

At present, data scheduled to be offered include: "chemical compound spectral data" built up by the chemical technical laboratory of the AIST regarding image information and the "AIST research activity image information," which is videotaped results of research.

The "chemical compound spectral data" will be provided online, and preparations are under way for the beginning of the service in FY87.

In addition, the image information will be initially offered in the form of VTR [videotape] in FY86.

Chapter 6. Japan Trust Project for International Research Cooperation

Japan, with its present economic power equal to 10 percent of the global GNP and its standards in many scientific and technological areas on a par with those of Europe and America, has shifted its emphasis from the importation of science and technology to the transfer of science and technology, and it is asked to contribute aggressively to the world.

In retrospect of Japan's development process, Japanese researchers have been accepted into the invitational systems for foreign researchers in Europe and America, including acceptance by the Humboldt Foundation of West Germany, and they have received major benefits. It is therefore an important role expected of Japan today to aggressively reciprocate such benefits.

Also, in order that Japan, which intends to establish a creative technology state, can aggressively promote creative technology and development in the future, it is important for the researchers of homogeneous Japan to strengthen the exchange with foreign researchers who entertain differing ideas from hetergeneous cultural and spiritual backgrounds.

Therefore, in FY85, the MITI and the MPT established a "Japan Trust Project for International Research Cooperation" to invite outstanding researchers from abroad on a large scale and for lengthy periods, and to promote creative technology development that will contribute to the world.

For this project, the Key Technology Center will be aided by operating profits of the public service trust fund established with contributions by private supporters of the projects. The Center will conduct the following affairs.

1) A survey of outstanding researchers abroad.

2) A survey of the needs of institutions accepting the researchers.

3) Draft basic plans for invitational projects based on the above surveys.

4) Select researchers to be invited.

5) Conduct publicity for the Japan trust project on international research cooperation.

6) Sponsor seminars with the invited researchers as panel members.

Researchers invited from abroad must, in principle, be holders of the equivalent of a Doctor of Philosophy degree, and will engage in the development of creative technology that will contribute to the world while deepening exchange with Japanese researchers.

In the past, 16 public service trusts have been established by interested donors. Beginning with this fiscal year, researchers will actually be invited from overseas.

Incidentally, this year is the 60th anniversary of the Emperor's reign, and a "Japan trust project to commemorate the Emperor's 60-year reign" will be promoted. As a link in this project, the "Japan trust to commemorate the 60th anniversary of the Emperor's reign"--a public service trust by subscribing donors--was established. The further growth of the Japan trust project for international research cooperation will thus be the goal, and on 10 and 11 December of this year, an international symposium is scheduled at the Keidanren Hall. President Keniichi Fukui of the Kyoto University of Industrial Arts and Textiles and other world-renown personalities from Japan and abroad will be invited as lecturers. Profound debates are expected on the role of international research cooperation for the creation of key technology in the 21st century.

Chapter 7. Survey Projects

Key technology is an area of the most rapid technological innovation. In view of the fact that active research and development is going on, not only in Japan but also in various foreign countries, it is necessary to accurately follow the trend of research and development by private enterprise in key technology, as well as policy trends at home and abroad. Based on the aforementioned viewpoints, the Key Technology Center is conducting broad surveys, including survey items of key technology accompanying the various business affairs at the Center, and providing information. It is thus promoting testing and research on key technology by the private sector.

Content of Survey Affairs

The scope of the surveys conducted by the Center includes the areas of new basic materials, biotechnology, machinery, electronics and telecommunications. In these areas, surveys of the technical ripple effects of key technology, surveys of testing and research trends, surveys of test evaluation methods and surveys of technology and development policies are conducted. As a condition for the conduct of the surveys, consideration is given as to whether the subject of a survey contributes considerably to the promotion of testing and research in key technology by the private sector, its urgency, whether it has large ripple effects and whether it is cross-sectional in terms of enterprises. Another consideration is whether it is necessary and highly urgent from the standpoint of carrying out the Center's affairs.

Putting the Survey Results Into Practical Use

The policy is to effectively use the survey results within the Center, and to provide information considered useful to the outside as much as possible. For this purpose, it is planned to review the possibility of publishing a technical information magazine, of conducting symposiums and of holding meetings to announce the results of surveys and research.

Track Record of Surveys

In FY85, the following surveys were conducted:

Surveys of trends in new basic materials technology: Survey methods and study of means for metal high polymers (molecules) and ceramic-type materials, a survey of present conditions concerning representative examples of new basic materials and a survey of technology trends in the United States concerning metal materials. The survey period was 3 years.

Survey of test evaluation methods for fine ceramics: A survey was conducted on the present conditions of evaluation methods on the mechanical nature of fine ceramics as structural materials, which urgently need the establishment of a test evaluation method. Items of testing and evaluation requiring speedy establishment in Japan were clarified. The survey period was 2 years.

Survey concerning measurement technology for extreme environments: A survey was conducted on actual conditions in the various areas of advanced technology. Present conditions concerning measurement technology for extreme environments (temperature zones, temperature standards, measured environments, and measurement means), in addition to overall trends concerning the points of issue, were clarified. The survey period was 2 years.

Survey of technological trends in telecommunications: Surveys and analyses were conducted on the systematization of telecommunications technology, the technological trends and prediction of dissemination, research and development potentials, reviews of existing technology evaluation methods and factors for the promotion of research and development in the field of telecommunications.

Overseas surveys: Spot surveys and watch surveys were conducted in Europe and America through JETRO [Japan External Trade Organization]. Interviews and data-gathering were conducted concerning the trend of key technology.

In FY86, as a continuation of FY85, it is planned to conduct surveys concerning measurement technology for extreme environments and for new areas of technology. Also, with respect to overseas surveys, spot surveys and watch surveys will be continued concerning technological trends in Europe and America.

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